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(54) **MODULAR WIRELESS LIGHTING CONTROL SYSTEM USING A COMMON BALLAST CONTROL INTERFACE**

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See application file for complete search history.

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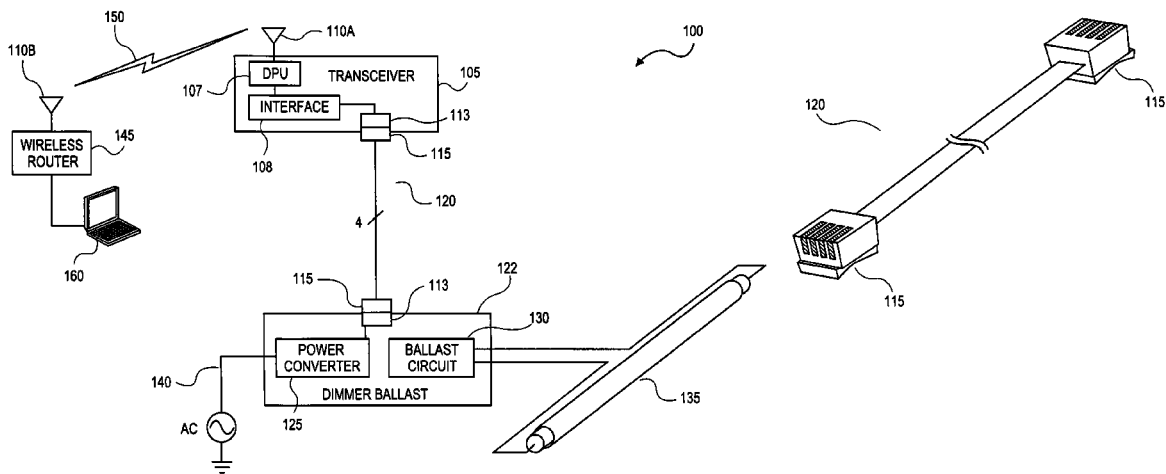
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(57) **ABSTRACT**

Disclosed is a modular lighting system that incorporates wireless technology and a standard interface. The lighting system may be installed in new buildings or retrofitted into existing buildings in such a way that provides many lighting configurations and programmability options while minimizing the amount of new wiring. The system includes a transceiver that controls one or more lamps using a dimming ballast or a relay and a low cost ballast. The dimming ballast, and the relay (if used) provide low voltage power to the transceiver over a cable having a standard interface, such as an RJ11 telephone jack. The transceiver provides on/off switching control and dimmer control, through the same cable, to the relay or dimming ballast. The transceiver can be located in the same room as the lamps it controls, or remotely located. A central computer or controller can control multiple transceivers over a wireless link.

18 Claims, 8 Drawing Sheets



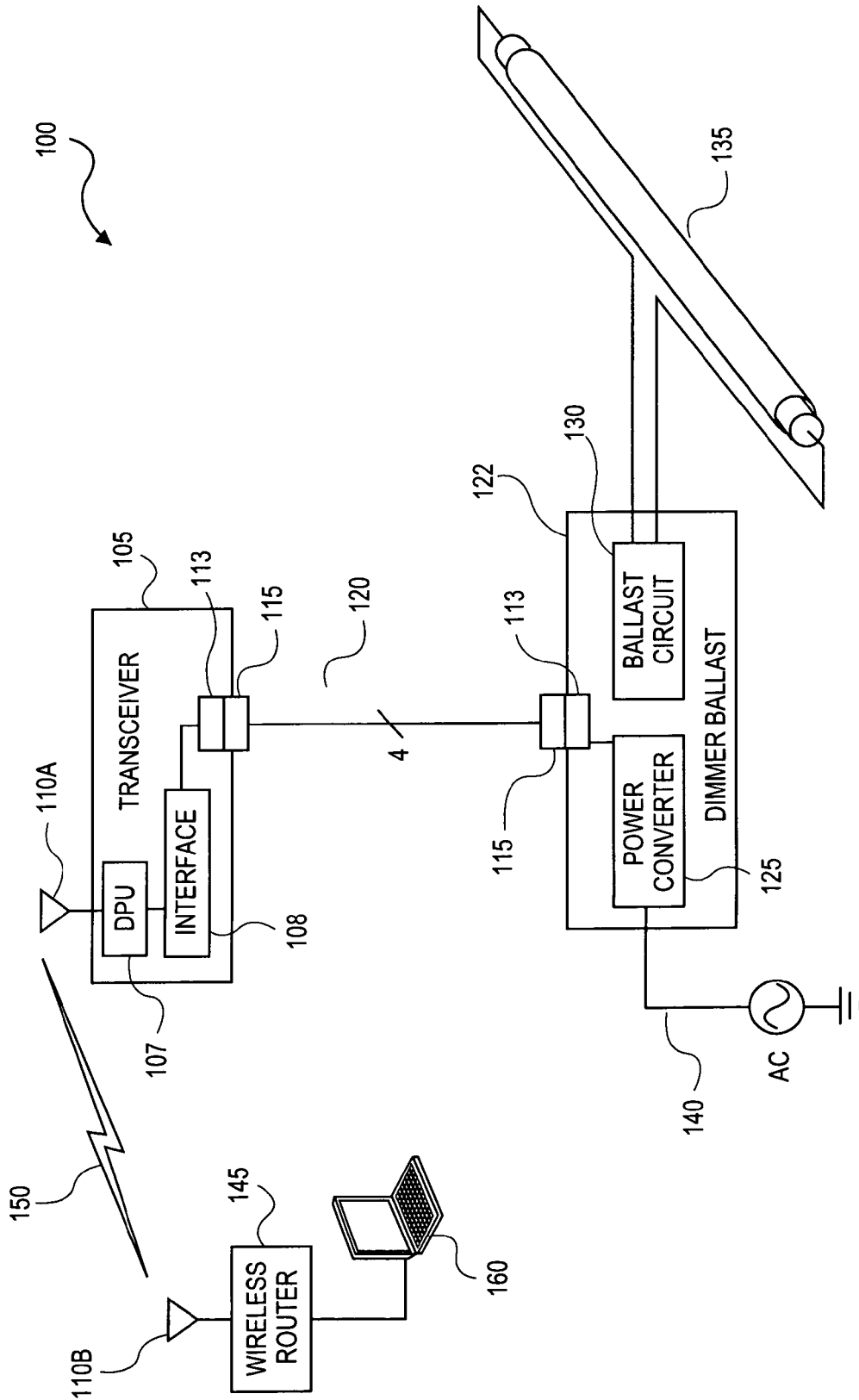


FIG. 1

FIG. 2A

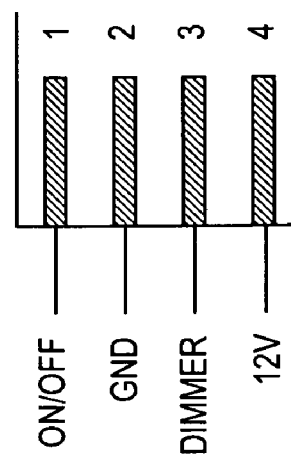
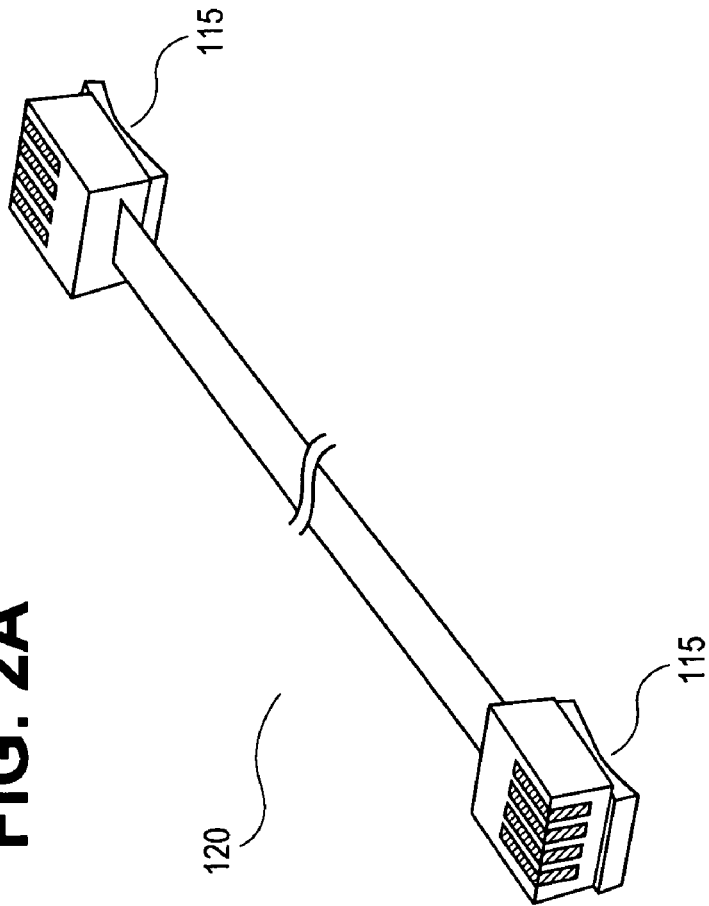


FIG. 2B

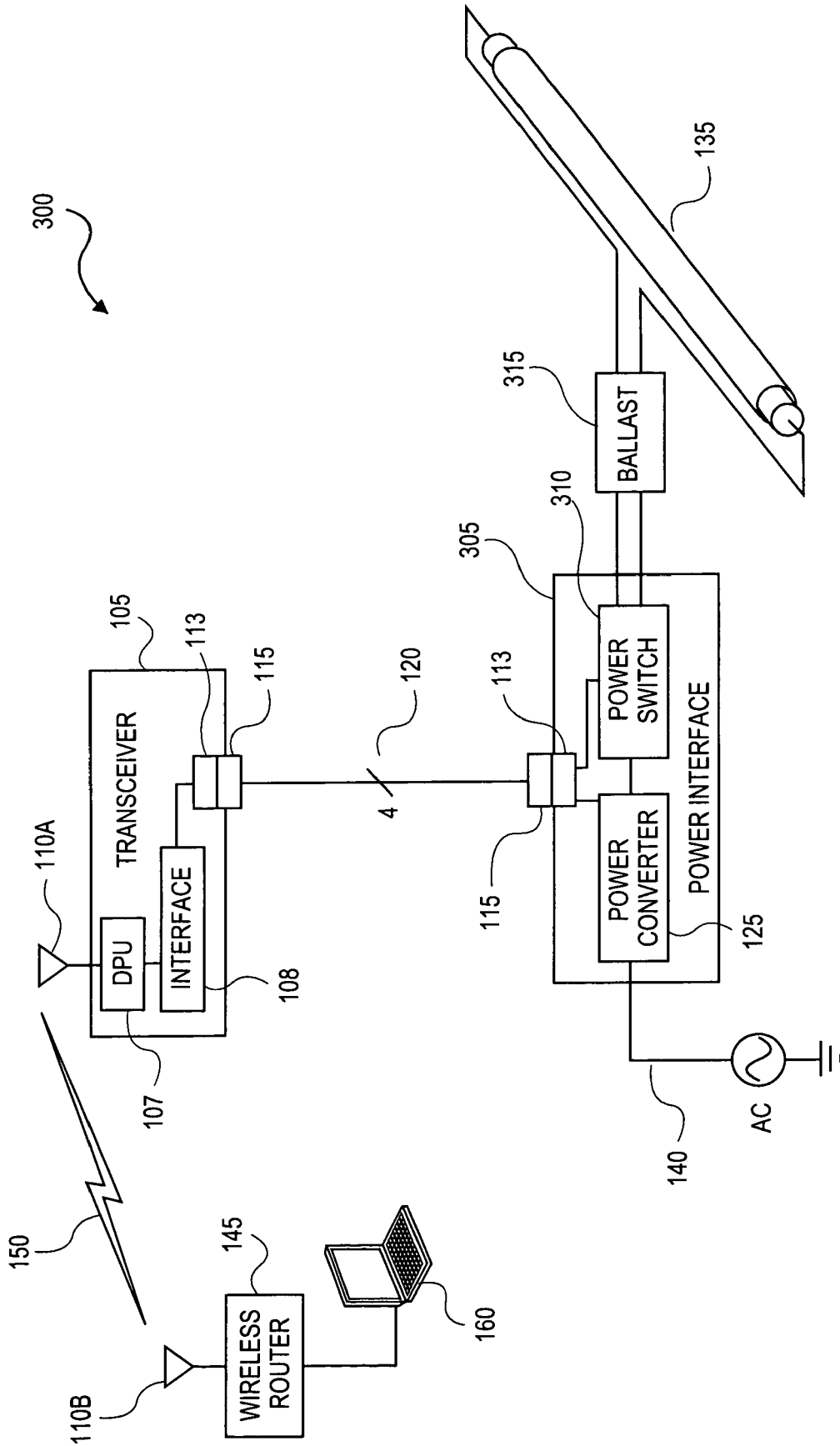


FIG. 3

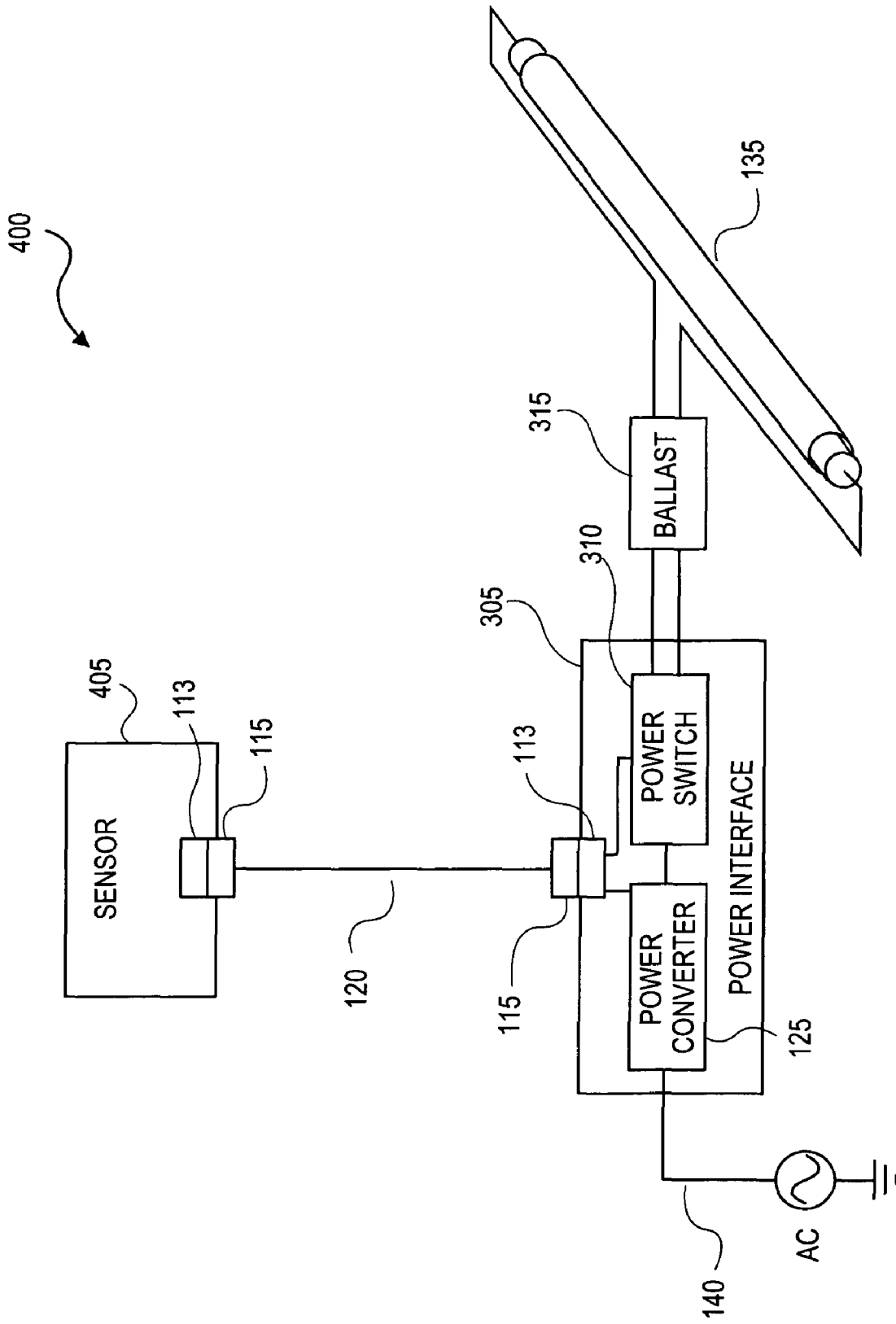


FIG. 4

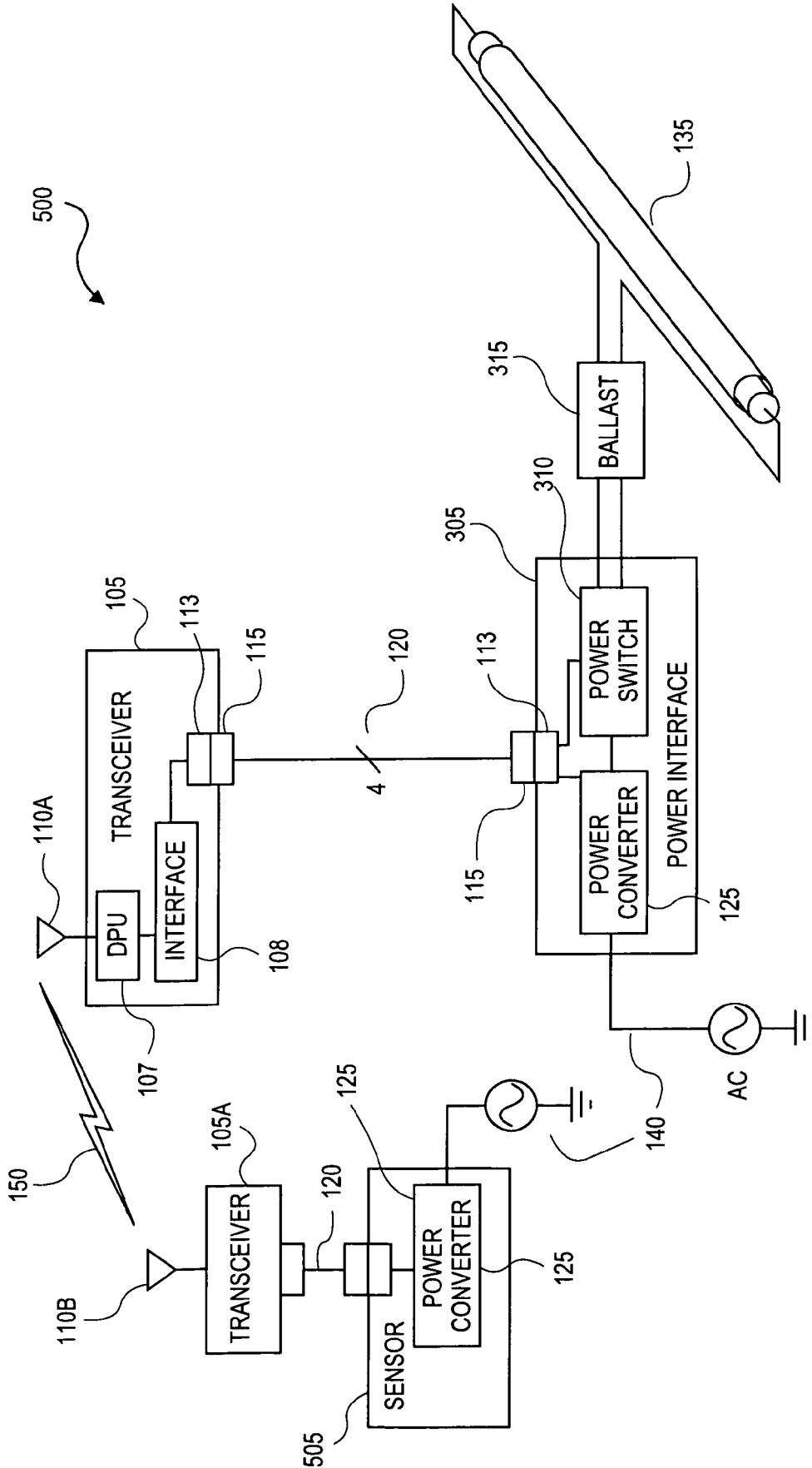


FIG. 5

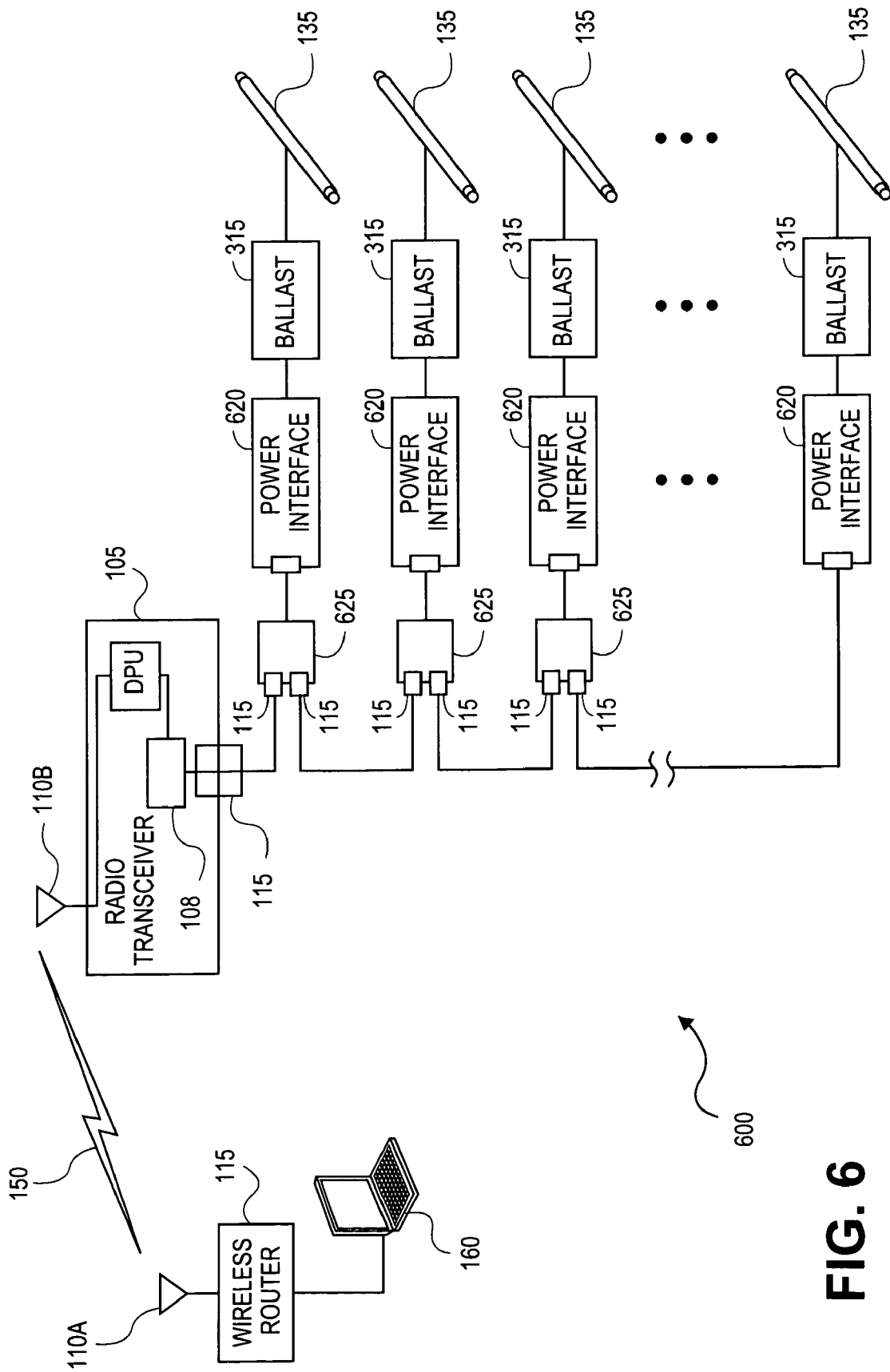


FIG. 6

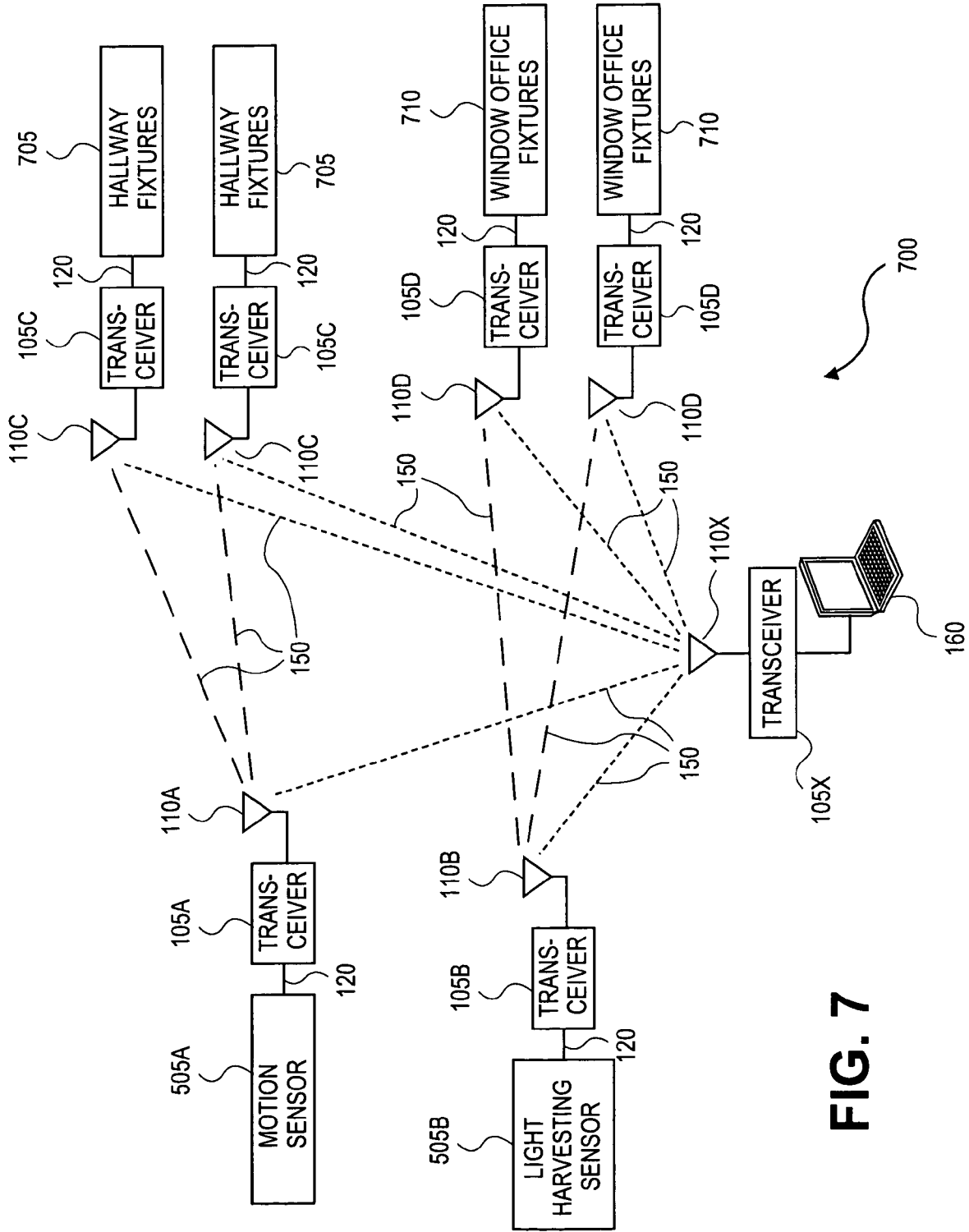


FIG. 7

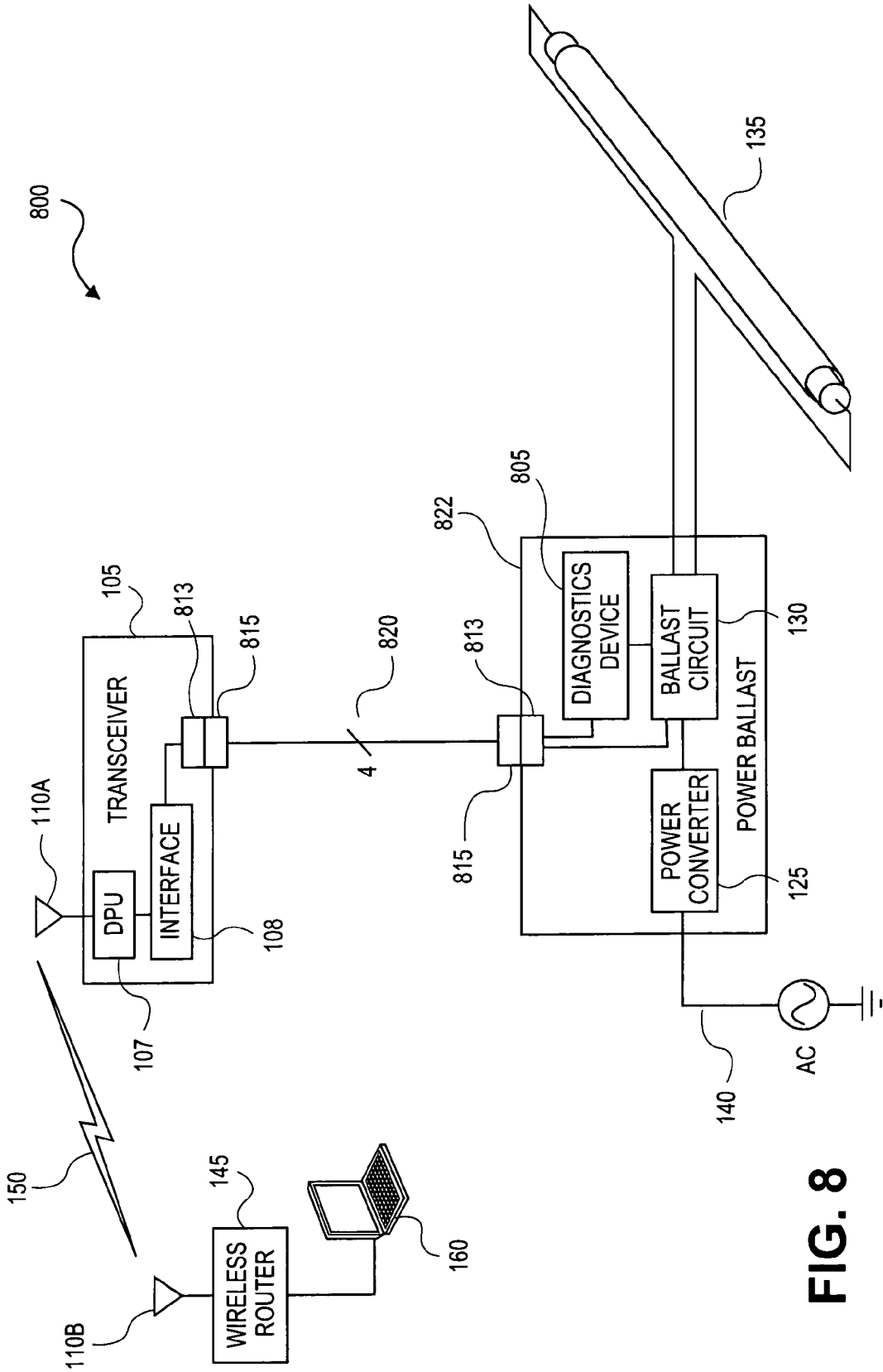


FIG. 8

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MODULAR WIRELESS LIGHTING CONTROL SYSTEM USING A COMMON BALLAST CONTROL INTERFACE

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention generally relates to lighting systems. More particularly, the present invention relates to lighting systems for residential or commercial structures in which energy conservation and ease of upgrading existing lighting systems are major concerns.

2. Discussion of the Related Art

Central lighting control systems, as used in commercial buildings, automatically turn lights on and off based on time of day. Many lighting control systems have included motion sensors and light harvesting sensors, which provide additional control in turning lights on and off. Motion sensors are typically used in areas, such as hallways or storage rooms, in which people are occasionally present. Light harvesting sensors, typically used in exterior offices with windows, turn lights on and off based on the presence of ambient sun light. The additional control provided by motion sensors and light harvesting sensors is intended to improve energy efficiency.

Central lighting systems typically use hard-wired switch relays on lighting circuits that are located in a central control box.

Central lighting control based on time of day, motion, and ambient sunlight, are expensive to implement. First, they are expensive to install because each individual circuit line feeder must be wired back to a central system. In many cases, these lighting systems are retrofitted into existing buildings, which is extremely labor intensive and generally cost prohibitive, especially in large commercial office buildings. Further, related art central lighting control systems are restricted to on/off functionality, because they rely on the use of relays. As such, dimming control is generally not available in a central lighting control system.

Second, lighting control systems that utilize motion, light harvesting, and time of use controls generally need to provide a secondary signal, such as a low voltage control signal, via a control wire that is connected to each of the lighting fixtures' ballasts. For instance, if two or three fixtures are controlled by a light harvesting sensor, each of the fixtures will need to be wired in parallel to the sensor. Accordingly, an electrician has to run a control wire from light fixture to light fixture and then back to the sensor. If two or three fixtures are to be controlled by a motion sensor, the same holds true in that the electrician has to run a control wire from fixture to fixture and then back to the motion sensor. The running of a control wire to each fixture is very expensive, which prevents most enterprises from retrofitting their offices with more energy efficient lighting control systems.

What is needed is a lighting control system that can be installed with minimal invasive wiring to the lighting circuit and the individual ballasts, enables dimming control, and can take advantage of motion sensors and light harvesting sensors to improve energy efficiency.

SUMMARY OF THE INVENTION

The present invention provides a modular wireless lighting control system using a common ballast control interface that obviates one or more of the aforementioned problems due to the limitations of the related art.

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Accordingly, one advantage of the present invention is that it reduces the expense of updating or retrofitting existing buildings with more efficient and advanced lighting control products.

Another advantage of the present invention is that it provides easier and more effective ways of controlling lighting to minimize energy consumption.

Still another advantage of the present invention is that it reduces the number of different types of lighting components used in a given structure.

Additional advantages of the invention will be set forth in the description that follows, and in part will be apparent from the description, or may be learned by practice of the invention. The advantages of the invention will be realized and attained by the structure pointed out in the written description and claims hereof as well as the appended drawings

To achieve these and other advantages, the present invention involves a lighting control system. The lighting control system comprises a transceiver having a data processing unit, an interface circuit, and a first plug that is connected to a first end of an interface cable; and a dimming ballast connected to a second end of the interface cable, wherein the dimming ballast is configured to provide a voltage to power the transceiver, and the transceiver is configured to provide an on/off control to the dimming ballast.

In another aspect of the present invention, the aforementioned and other advantages are achieved by a lighting control system, which comprises a sensor; a power interface connected to the sensor by an interface cable; and a ballast connected to the power interface, wherein the power interface is configured to provide, over the interface cable, a voltage to power the sensor, and wherein the sensor is configured to provide, over the interface cable, an on/off signal to the ballast.

In another aspect of the present invention, the aforementioned and other advantages are achieved by a transceiver for a wireless lighting control system. The transceiver comprises a data processing unit; an interface circuit connected to the data processing unit; and a jack that is connectable to an interface plug, the jack having a first pin corresponding to an on/off signal, a second pin corresponding to a ground signal, and a third pin corresponding to a voltage power signal that provides power to the transceiver, wherein the data processing unit has a computer readable medium encoded with a program for receiving a command signal from an external controller and for sending a control signal to the interface circuit, wherein the control signal corresponds to the command signal, and wherein the on/off signal is a function of the control signal.

In another aspect of the present invention, the aforementioned and other advantages are achieved by an interface device for a lighting system, which comprises a cable having a plurality of conductors; and an interface plug disposed at an end of the cable, wherein the interface plug has a first pin that conducts an on/off signal from a host device to a lamp ballast device, a second pin that conducts a ground signal from the lamp ballast device to the host device, and a third pin that conducts a low voltage signal from the lamp ballast device to the host device for providing power to the host device, wherein the first pin, the second pin, and the third pin correspond to the plurality of conductors.

In another aspect of the present invention, the aforementioned and other advantages are achieved by a power interface device for a lighting control system, which comprises a power converter; a power switch; and a jack connected to the power converter and the power switch, wherein the jack has a first pin that corresponds to an On/Off signal, wherein the first pin

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is connected to the power switch; a second pin that corresponds to a ground signal, wherein the second pin is connected to the power converter; and a third pin that corresponds to a DC voltage, wherein the third pin is connected to the power converter.

It is to be understood that both the foregoing general description and the following detailed description are exemplary and explanatory and are intended to provide further explanation of the invention as claimed.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings, which are included to provide a further understanding of the invention and are incorporated in and constitute a part of this specification, illustrate embodiments of the invention and together with the description serve to explain the principles of the invention.

FIG. 1 illustrates an exemplary system employing wireless control of a dimming ballast;

FIG. 2A illustrates an exemplary interface cable according to the present invention;

FIG. 2B illustrates an exemplary pin assignment for the interface cable of FIG. 2A;

FIG. 3 illustrates an exemplary system employing wireless control of a power interface circuit of the present invention connected to a standard ballast;

FIG. 4 illustrates an exemplary system using a sensor to control a power interface circuit connected to a standard ballast;

FIG. 5 illustrates an exemplary system using a sensor to control a standard ballast over a wireless connection;

FIG. 6 illustrates an exemplary system employing wireless control of a plurality of relays to control a lighting system using standard ballasts;

FIG. 7 illustrates an exemplary system employing wireless control to use a combination of light harvesting sensors and motion control sensors to control a plurality of light fixtures according to the present invention; and

FIG. 8 illustrates a variation to the system illustrated in FIG. 1 that includes a lamp life diagnostic device.

DETAILED DESCRIPTION OF THE ILLUSTRATED EMBODIMENTS

The present invention involves the use of a standard interface that provides wireless control of a ballast while minimizing the electromagnetic interference that a ballast transformer would impart on a wireless transceiver. The standard interface enables different lighting components, such as motion sensors, light harvesting sensors, relays, etc., to derive power, such as DC power, from the ballast and provide control signals, such as dimming control, to the ballast. The standard interface enables one to easily design and install one or more lighting systems for a room with minimal invasive wiring. Further, by using modular components that connect to the standard interface, and a standard interface cable, a building can have a variety of lighting configurations in different rooms while minimizing the number of different parts to maintain in inventory. Additionally, by using modular components with standard interfaces, and by incorporating wireless technology, existing buildings can be retrofitted with advanced lighting systems without the need for new wires to be run through the building. Still further, as new modular components enter the market, they may be integrated into existing modular lighting systems according to the present invention with reduced effort and time to install.

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FIG. 1 illustrates an exemplary system 100 that employs wireless control of a dimming ballast according to the present invention. System 100 includes a transceiver 105 having an antenna 110a; a wireless router 145 that uses an antenna 110b to communicate with transceiver 105 over a wireless link 150; and a user interface computer 160 connected to wireless router 145. Transceiver 105 is connected to a dimming ballast 122 over an interface cable 120, which has an interface plug 115 at either end. Dimming ballast 122 may have a jack 113, which mates with interface plug 115, a power converter 125, and a ballast circuit 130. Dimming ballast 122 may derive power from an AC source 140 (e.g., 120V or 277 V). Further, dimming ballast 122 may be connected to a lamp 135.

User interface computer 160 may include one or more commercially available computers that is/are connected to wireless router 145 over a network, which may include the internet. Alternatively, user interface computer 160 may be a controller device, such as a commercially available wall-mounted control unit, which may be mounted on a wall of the room (or nearby room) in which system 100 is installed. User interface computer 160 may control system 100 by using special purpose software, or by using a web-based control software that runs on a browser. A further discussion of internet-based control of a lighting system can be found in published U.S. Patent Application, Publication No. 20050097162, WIRELESS INTERNET LIGHTING CONTROL SYSTEM, which is incorporated by reference as if fully disclosed herein.

Transceiver 105 and wireless router 145 may communicate over wireless link 150 using one or more of a number of wireless communications schemes, such as fixed frequency, spread-spectrum, ultra wide-band, WiFi (IEEE 802.11), Zigbee (IEEE 802.15.4), Bluetooth, Mesh, etc. Non RF-based communication schemes, such as infrared, or Power Line Carrier (PLC) implementations, are possible and within the scope of the invention. The communication scheme implemented for radio link 150 need not require high bandwidth, because light control information sent from wireless router 145 to transceiver 105 would not occur very often. Wireless link 150 may need to be sufficiently robust to penetrate multiple walls, such as in a large commercial structure. Further, repeaters (not shown) may be used to extend the range of wireless link 150. Antennas 110a and 110b may be compatible with one or more of the above communication schemes chosen for wireless link 150. As such, antennas 110a and 110b may each be one antenna or multiple antennas, depending on the chosen communication scheme or schemes. It will be readily apparent to one skilled in the art that many architectures for implementing wireless link 150 are possible and within the scope of the invention.

Transceiver 105 may have an antenna 110a, a data processing unit 107, a jack 113, and an interface circuit 108 connected jack 113. Data processing unit 107 may contain a processor or microcontroller, which may include and a memory encoded with embedded software for establishing a communication bridge over wireless link 150, identifying devices connected to the transceiver 105, and for controlling any connected devices in response to commands from interface computer 160. Data processing unit 107 may derive power from interface circuit 108 and may provide control signals to jack 113 via interface circuit 108. Data processing unit 107 may also include antenna interface and signal conditioning circuitry through which it is connected to antenna 110a.

Transceiver 105 may further include a binary switch, such as a dip switch (not shown), which may be set to a binary value that corresponds to an address for transceiver 105.

Accordingly, if multiple transceivers **105** are used in a lighting system, each may be given independent addresses (by setting the dip switch) so that user interface computer **160** may command each transceiver **105** independently. Further, in a lighting system having many transceivers, one or more groups of transceivers **105** may be given the same address so that user interface computer may simultaneously command multiple lighting fixtures identically. The use of a dip switch is exemplary; other address-setting mechanisms may be used and are within the scope of the invention.

FIG. 2A illustrates an exemplary interface cable **120** that connects the modular components described herein. Interface cable **120** may come in various lengths, depending on the size of the room in which system **100** (or any the later-described systems) is to be installed. Interface plug **115** may be one of several standard telephone plugs commonly in use. For example, interface plug **115** may be a small Class 1 or 2 telephone plug, such as an RJ11, RJ14, or RJ45 plug. Other plugs may be used provided that they have a sufficient number of conductors and are easy to connect and disconnect in hard to reach locations. Interface cable **120** may be used to connect any of the components discussed herein.

FIG. 2B illustrates an exemplary pin assignment for interface plug **115**. If an RJ11 plug is to be used, an exemplary pin assignment may be as follows. Pin **1** is assigned an On/Off signal for controlling dimming ballast **122**; pin **2** is assigned a ground, which may be the same as a low voltage dimmer ground; pin **3** is assigned a 0-10V dimmer line; and pin **4** is assigned a 12V regulated or 15-21V unregulated (50 mA max) power source line, also referred to herein as a low DC voltage. It will be readily apparent to one skilled in the art that variations to this pin assignment, and variations to the voltages and signals therein, are possible and within the scope of the invention.

Referring again to FIG. 1, dimming ballast **122** provides power to transceiver **105**, and transceiver **105** provides control signals to dimming ballast **122**, over interface cable **120**. Dimming ballast **122** includes a power converter **125** and a ballast circuit **130**. Power converter **125** may down convert AC power from AC source **140** into a low DC voltage (for example, 5-12V, although other voltage ranges, such as 3.3V or 5V to 12V are possible). Further, power converter **125** may generate an unregulated voltage, such as a 21V unregulated signal, for the low voltage DC signal. The specific low DC voltage generated by power converter **125** may depend on the power requirements of transceiver **105**. Power converter **125** may use one of a number of methods for power conversion. For example, power converter **125** may include a switching power supply, or a transformer with a rectifier circuit. Power converter **125** may also do direct AC conversion. Power converter **125** also provides AC power to ballast circuit **130**.

Power converter **125** provides the low DC voltage signal to interface plug **115** (pin **4** in the above example) via a jack **113** to which interface plug **115** attaches. Power converter **125** may include a diode to limit the direction of the power output of the low voltage signal. For example, a diode that limits current to 50 mA, such as a 1N4148 diode, may be used. Other diodes may be used, depending on the gauge of the pins in interface plug **115**, the gauge of the conductors in interface cable **120**, and the expected power requirements of transceiver **105**.

The low DC voltage signal generated by power converter **125** is received by interface circuit **108** of transceiver **105** via pin **4** of interface plug **115**. Interface circuit **108** may process the voltage signal, such as by filtering it and/or stepping it up or down with a DC/DC converter or the like, for the sake of powering the components in transceiver **105**.

Interface circuit **108** may have an open collector analog circuit connected to pin **1** of interface plug **115**, whereby pulling pin **1** to ground will shut off power to dimming ballast **122**. However, one skilled in the art will appreciate that other circuit configurations for switching dimming ballast **122** on and off are possible and within the scope of the invention.

Interface circuit **108** may apply the analog dimmer voltage to pin **3** in a variety of ways. For example, interface circuit **108** may have a variable resistor that is controlled by a printed wiring board (PWB) FET. Alternatively, interface circuit **108** may implement a D/A converter using an "R2R" resistor ladder array. It will be readily apparent to one skilled in the art that many such implementations of interface circuit **108** are possible and within the scope of the invention.

Because transceiver **105** is spaced apart from power converter **125**, ballast RF noise resulting from RF interference generated by power converter **125** is substantially mitigated. Further, because transceiver **105** draws its power from dimming ballast **122**, no additional wiring is required for transceiver **105**. Accordingly, transceiver **105** may be placed so that it is easily accessible, or for optimal reception by antenna **110a**, with the only wiring constraint that it be reachable by interface cable **120**. Further, retrofitting dimming ballast **122** in an existing fixture would not require any new wiring because its only connections are to AC source **140**, which would be pre-existing, and interface cable **120**.

System **100** may function as follows. Transceiver **105** receives commands from user interface computer **160** via wireless router and wireless link **150**. Data processing unit **107** receives the commands from antenna **110a** and converts these commands into instructions for dimming ballast **122**. Data processing unit **107** then sends the instructions to interface circuit **108**, which converts these instructions into signals that it sends to ballast circuit **130** via interface cable **120**. For example, if the instruction is to turn lamp **135** on or off, data processing unit **107** may instruct interface circuit **108** to apply the corresponding voltage to the On/Off signal assigned to pin **1** (in the above exemplary pin configuration). If the command from user interface computer is to dim lamp **135**, or otherwise modulate the brightness of lamp **135**, data processing unit **107** instructs interface circuit **108** to provide a corresponding analog voltage (e.g., within a 0-10V range) to the dimmer line assigned to pin **3** on jack **113**.

If the instruction is to adjust dimmer in dimming ballast **122**, data processor unit **107** may apply an appropriate digital value to a digital to analog (D/A) converter (not shown), which then applies the analog voltage to the dimmer signal assigned to pin **3** of interface plug **115**. This dimmer voltage is received by ballast circuit **130** (via interface cable **120**), which in turn applies the corresponding power to lamp **135**.

Variations to system **100** are possible. For example, ballast circuit **130** may be a commercial dimming ballast that provides a low voltage DC output from internal power conversion circuitry (not shown). If this is the case, power converter **125** may not be necessary. In such a case, dimming ballast **122** may include an interface that connects the appropriate pins in jack **113** to the appropriate leads in the commercial dimming ballast. The interface, and the jack **113**, may take the form of a retrofit kit, which may be easily integrated with the commercial dimming ballast. It will be readily apparent to one skilled in the art that such variations of system **100** are possible and within the scope of the invention.

FIG. 3 illustrates an exemplary system **300** employing wireless control of a relay connected to a standard ballast. System **300** includes a transceiver **105** that communicates with a wireless router **145** over a wireless link **150**, similarly to system **100**. A difference between system **300** and system

100 is that system 300 uses a standard ballast 315 that does not have a dimmer feature. Here, a ballast 315 is connected to a power interface 305, which is connected to transceiver 105 via interface cable 120.

Power interface 305 may have a power converter 125, like that in system 100, and a power switch 310, which may act as a relay in providing power to ballast 315. Power switch 310 may be a commercially available relay that is connected to jack 113 and power converter 125. Alternatively, power switch may be a semiconductor switch, such as a triac switch. Any such switch may be used provided that it accepts an On/Off signal like that which can be provided by interface circuit 108, and that can switch sufficient power to drive lamp 135, which may be one or more lamps. One skilled in the art will readily recognize that various switch devices may be used for power switch 310, all of which are within the scope of the invention.

In system 300, power converter 125 converts the AC voltage from AC source 140 into a low voltage DC signal in a manner similar to that described with respect to system 100 above. Power converter 125 applies this voltage to pin 4 of jack 113, which provides power to transceiver 105 in a manner similar to that described above.

The exemplary process for switching on and off dimming ballast 122 in system 100 is substantially similar to that for system 300 here. However, in system 300, transceiver 105 sends the On/Off signal to power switch 310 (instead of ballast circuit 130) via pin 1 of interface plug 115 to switch ballast 315 on and off.

In system 300, ballast 315 may also be one of any low-cost commercially available ballasts, which is connected to power converter 125 and jack 113 via leads provided with ballast 315. In system 300, the dimmer signal, which is assigned to pin 3 of exemplary pin assignment above, is not used. As such, the same transceiver 105 and interface cable 120 may be used in either of systems 100 and 300.

FIG. 4 illustrates an exemplary system 400 using a sensor 405 to control a standard ballast. Sensor 405 may be a light harvesting sensor, a motion sensor, or some other device that can be used to switch lights on and off in response to a certain condition. The remaining components in system 400 may be the same as those described in system 300 above. In system 400, sensor 405 draws low voltage DC power from pin 4 of interface plug 115, which is derived from AC power source 140 by power converter 125. This is similar to how transceiver 105 draws power in system 300.

In the case in which sensor 405 is a light harvesting sensor, system 400 may be installed in a room that occasionally receives sunlight, or light from another source. When sensor 405 (as a light harvesting sensor) detects ambient light from another source, it sends a signal to On/Off pin 1 of interface plug 115, which switches off power switch 310 via interface cable 120. Conversely, when sensor 405 detects an absence of ambient light, it sends a signal to On/Off pin 1 of interface plug 115, which switches on power switch 310 via interface cable 120.

Sensor 405 may have its own wireless transceiver (not shown), whereby sensor 405 may be controlled (e.g., enabled/disabled) via a wireless link (not shown) in a manner similar to that of systems 100 and 300. In this case, sensor 405 may have a digital switch, such as a dip switch, that enables sensor 405 to be independently addressed by a wireless control network (not shown). It will be readily apparent to one skilled in the art that such variations are possible and within the scope of the invention.

In an alternative to system 400, power interface 305 and ballast 315 may be replaced with dimming ballast 122 of

system 100. In the example in which sensor 405 is a light harvesting sensor, sensor 405 may detect ambient light and send an analog voltage (such as in a 0-10V range) to dimmer pin 3 of interface plug 115. This analog voltage is received by ballast circuit 140 in dimming ballast 122, which may control the output of lamp 135 in response to the ambient light detected by sensor 405. In this manner, the amount of light in a room may be held constant in the presence of changing sunlight conditions while minimizing power consumption by lamp 135.

In another example, sensor 405 may be a motion sensor. In this case, system 400 may be installed in an area such as a hallway or a storage room, in which people are intermittently present. In this example, on detecting motion, sensor 405 (a motion sensor) sends a signal to On/Off pin 1 of interface plug 115, which switches on power switch 310 via interface cable 120, which in turn switches on lamp 135. After a prescribed amount of time (programmed into motion sensor example of sensor 405) in which motion has not been detected, sensor 405 sends a signal to On/Off pin 1 on interface plug 115, which switches off power switch 310, which in turn switches off lamp 135.

System 400 may be standalone system (i.e., "island control"), which operates independently of any external control. Further, system 400 may use a different type of sensor 405 other than a motion sensor or a light harvesting sensor. In any case, sensor 405 may draw power from the voltage provided on pin 4 of interface plug 115, and provide an On/Off signal on pin 1 of interface plug 115. Further, system 400 may use a dimming ballast 122 in place of the power interface/ballast combination illustrated in FIG. 4. If a dimming ballast 122 is used, sensor 405 may provide a dimmer signal on pin 3 of interface plug 115. It will be readily apparent to one skilled in the art that such variations are possible and within the scope of the invention.

As used herein, the term "lamp ballast device" may refer to dimming ballast 122 of system 100 or the combination of power interface 305 and ballast 315 of system 300. Further, the term "host device" may refer to any of the transceivers or sensors described herein that provides on/off control to a lamp ballast device and receives voltage power signal from a lamp ballast device.

FIG. 5 illustrates an exemplary system 500 that implements wireless control of a lighting system based on the output of a sensor 505. Here, sensor 505 may be, for example, a motion sensor or a light harvesting sensor, although other types of sensors may be used. System 500 may be substantially similar to systems 100 and 300 described above, with sensor 505 taking the place of user interface computer 160.

Sensor 505 may have a power interface 125, which converts AC power into a low DC voltage signal that is provided to a transceiver 105a that is connected to sensor 505 by interface cable 120. Transceiver 105a may be substantially similar to transceiver 105 that is connected to power interface 305.

System 500 may work as follows. Sensor 505 detects an event that warrants switching on lamp 135. If sensor 505 is a motion detector, the event may be motion in the vicinity of sensor 505. If sensor 505 is a light harvesting sensor, the event may be a change in ambient lighting conditions. Either way, sensor 505 sends a signal to transceiver 105a to turn on lamp 135. In doing so, sensor 505 may provide a signal through the On/Off pin 1 of interface plug 115, or through dimmer control pin 3 on plug 115.

Transceiver 105a receives the signal from sensor 505. In doing so, the interface circuit (not shown) in transceiver 105a may respond to a change in voltage at the appropriate pin on

interface plug **115**, and provide a signal to the data processing unit (not shown) in transceiver **105a**. The data processing unit may issue a command that is transmitted over wireless link **150**. Transceiver **105** receives the command and in response turns on lamp **135** in a manner similar to that described above with regard to system **300**.

System **500** may be deployed in many ways. For example, if sensor **505** is a light harvesting sensor, it could provide lighting control to all the south-facing offices in a building. Similar variations are possible if sensor **505** is a motion sensor, or any other appropriate type of sensor. Further, sensor **505** may be controlled by a computer (not shown) that communicates with sensor **505** over another wireless link **150**. It will be readily apparent to one skilled in the art that many variations to system **500** are possible and within the scope of the invention.

FIG. **6** illustrates an exemplary system **600** employing wireless control of a plurality of relays to control a lighting system using standard ballasts. System **600** may be considered similar to system **400**, but with multiple lamp ballast device combinations that enable variable lighting control in a room using low-cost ballasts. Variable lighting may be achieved by turning on/off different combinations of lamps in a “checkerboard” fashion.

System **600** includes a transceiver **105** and a plurality of power interfaces **620**, each of which is connected to a ballast **315**. Power interfaces **620** may be connected to transceiver **105** by an interface cable **120** in a “daisy chain” configuration.

Transceiver **105** is connected to first power interface **620** by a single power interface cable **120** via a Y combiner **625**. Power interface cable **120** is connected to a first input of Y combiner **625**, and the other input of Y combiner is connected to a second power interface cable **120** that is connected to another Y combiner **625**. Each Y combiner **625** has an output that respectively connects to a power interface **620**. In this fashion, a plurality of ballasts **315** can be daisy chained.

Each Y combiner **625** may be a standard 2:1 RJ-11 Y combiner. Each Y combiner may have two female input jacks and a male plug. Each Y combiner **625** may be a commercially-available device.

Each power interface **620** is connected to an AC source (not shown) in a manner similar to power interface **305** discussed above. Each power interface **620** has a power converter (not shown) and a power switch (not shown) that are substantially similar to the power converter **125** and power switch **310** in power interface **305**. Power interface **620** interface further includes a diode connected in series from the power converter, wherein the diode’s cathode is toward interface jack **115**. This may prevent back-flow of power from a given ballast **315** to the next ballast **315** of system **600**. Accordingly, system **600** enables ballasts **315** to be connected to transceiver **105** in various series and parallel combinations.

Lighting may be modulated in a room in a checkerboard fashion by having two instantiations of system **600** within a room, wherein each instantiation may have a plurality of ballasts **315** daisy-chained together. For example, a first system **600**, which as a first plurality of ballasts **315** daisy-chained together, receives a command from user interface computer **160** (via wireless link **150**) to switch on or off. A second system **600**, which has a second plurality of ballasts **315** daisy-chained together, receives a separate command, independent of the command to first system **600**, to switch on and off. In this manner, lighting in a room may be modulated at discrete levels according to the number of ballasts **315** respectively in first system **600** and second system **600**. One skilled in the art that many combinations of systems **600**, and

different pluralities of ballasts **315** for each system **600**, are possible and within the scope of the invention.

FIG. **7** illustrates an exemplary system **700** employing wireless control to use a combination of light harvesting sensors and motion control sensors to control a dimming ballast according to the present invention. System **700** includes a user interface computer **160** connected to a transceiver **105x**; a motion sensor **505a** connected to a transceiver **505a** by an interface cable **120**; and a light harvesting sensor **505b** connected to a transceiver **105b** via an interface cable **120**. System **700** further includes one or more set of hallway fixtures **705**, wherein each set of hallway fixtures **705** is connected to a transceiver **105c** by an interface cable **120**; and one or more set of window office fixtures **710**, wherein each set of window office fixtures **710** are connected to a transceiver **105d** by an interface cable **120**.

Transceivers **105c**, which are connected to sets of hallway fixtures **705**, may each be given the same address so that all of the hallway fixtures **705** may be commanded to turn on and off simultaneously. Similarly, transceivers **105d** may each be given the same address. In doing so, the dip switches (not shown) on each of the transceivers **105c** and **105d** may be set accordingly.

System **700** may operate as follows. Motion sensor **505a** detects motion in its vicinity and sends a signal to transceiver **105a**, via interface cable **120**, to command hallway fixtures **705** to turn on. In doing so, transceiver **105a** broadcasts a message over wireless link **150** using antenna **110a**. The message broadcast by transceiver **105a** includes the address set in transceivers **105c**. Transceivers **105c** respond to the message broadcast by transceiver **105a**, based on the address set in their respective dip switches (not shown). Transceivers **105c** in turn respectively send a signal to turn on the hallway light fixtures **705**. In doing so, transceivers **105c** apply a signal to the On/Off pin **1** of the interface jack (not shown) of interface cable **120**.

Light harvesting sensor **505b** detects a change in ambient light such that it sends a signal to transceiver **105b** to turn on or off window office fixtures **710**. In doing so, light harvesting sensor **505b** sends a signal to transceiver **105b**, which broadcasts an appropriate message over wireless link **150** using antenna **110b**. The message broadcast by transceiver **105b** includes the address set in the dip switches (not shown) on transceivers **105d**. Transceivers **105d**, based on their addresses, receive the message broadcast by transceiver **105b** and process the instructions accordingly. In turn, transceivers **105d** send a signal to their respective window office fixtures **710** via interface cable **120**. In doing so, transceivers **105d** apply a signal to the On/Off pin **1** of the interface jack (not shown) of interface cable **120**.

Both of the above functions are substantially similar to that performed by system **500** described above. System **700** may be considered as including two systems **500**, one with a motion sensor **505a**, and another with a light harvesting sensor **505b**.

Referring again to FIG. **7**, user interface computer **160** may be programmed to override the commands provided by transceivers **105a** and **105b**, thereby taking direct control of hallway fixtures **705** and window office fixtures **710**. In doing so, user interface computer **160** may send an instruction to transceiver **105x**, which is broadcast over wireless link **150** using antenna **110x**. The message may include addresses set in the dip switches (not shown) of transceivers **105c** and **105d**. One message may be sent to both sets of transceivers, or two messages may be sent, one to transceivers **105c** and another to transceivers **105d**. The message sent by transceiver **105x** may include instructions to turn on or off hallway fixtures **705**

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and/or window office fixtures **710**. The message sent by transceiver **105x** may also include an instruction to disregard any instructions received from motion sensor **505a** and/or light harvesting sensor **505b**.

Further to system **700**, user interface computer **160** may be used to configure motion sensor **505a** and light harvesting sensor **505b**. For this scenario, transceivers **105a** and **105b** may have unique addresses set in their respective dip switches (not shown). User interface computer **160** may send instructions to transceiver **105x** to broadcast a message to each of transceivers **105a** and **105b**. The messages may respectively include the address of the transceiver **105a** or **105b**, and a given configuration command for the motion sensor **505a** or the light harvesting sensor **505b**.

Although the above exemplary operation description for system **700** involves turning on and off hallway fixtures **705** and window office fixtures **710**, it may also include dimmer commands. One skilled in the art will readily recognize that different operation scenarios are possible and within the scope of the invention.

FIG. **8** illustrates a variation of system **800** in which dimming ballast **822** includes a lamp life diagnostic device **805**. Diagnostics device **805** detects lamp life by monitoring the power drawn by ballast circuit **130**. Diagnostics device **805** provides lamp life information to transceiver **105** interface cable **820** having interface plugs **815**. In order to accommodate this additional information, system **800** has includes a ballast interface cable **820** with at least one additional conductor. Also, the interface plugs **815** on ballast interface cable **820**, and the corresponding jacks **813**, each have at least one additional pin corresponding to the additional conductor(s). Here, interface plug **815** may be an RJ14 telephone jack, although other similar jacks or plugs may be used, provided that it has a sufficient number of conductors and can be easily connected or disconnected in hard to reach places.

Variations to the embodiments described above are possible and within the scope of the invention. For example, interface plug **115** may have additional conductors, as discussed above, in which an eight pin RJ45 plug may be used for interface cable **120**. In this case, additional signals may be incorporated into the standard interface according to the present invention. Additional signals may include, for example, a lamp outage detection signal. One skilled in the art will readily appreciate that such variations are possible and within the scope of the invention.

In a variation to system **500**, sensor **505** may derive power from power interface **305**, instead of having its own AC power source **140**. This variation may make use of the Y combiner **625** discussed with regard to exemplary system **600** above. Referring to FIG. **5**, a Y combiner (not shown) may be introduced between transceiver **105** and power interface **305** such that the output of the Y combiner is connected to jack **113** of power interface **305**. Interface cable **120** may connect transceiver **105** to one input of the Y combiner, and a second interface cable (not shown) may be connected to the Y combiners' other input. The other end of the second interface cable is connected to a second jack (not shown) in sensor **505**, which is designated for input power only. In this configuration, power converter **125** of power interface **305** may provide power to sensor **505** and transceivers **105** and **105a**. In this variation to system **505**, only one connection to AC source **140** may be necessary.

It will be apparent to those skilled in the art that various modifications and variations can be made in the present invention without departing from the spirit or scope of the invention. Thus, it is intended that the present invention cover

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the modifications and variations of this invention provided they come within the scope of the appended claims and their equivalents.

What is claimed is:

1. A lighting control system, comprising:

a transceiver having a data processing unit, an interface circuit connected to the data processing unit, and a first plug that is connected to a first end of an interface cable having a first pin corresponding to an on/off signal, a second pin corresponding to a ground signal, a third pin corresponding to a voltage power signal that provides power to the transceiver, and a fourth pin corresponding to a dimming signal, the data processing unit having a computer readable medium encoded with a program for receiving a command signal from an external controller and for sending a control signal to the interface circuit, wherein the control signal corresponds to the command signal and the on/off and dimming signals are a function of the control signal; and

a dimming ballast connected to a second end of the interface cable, wherein the dimming ballast is configured to provide a voltage to power the transceiver over the interface cable, and the transceiver is configured to provide the on/off and dimming signal to the dimming ballast over the interface cable;

wherein the transceiver further includes a jack configured to relay the on/off and dimming signal control to a second transceiver.

2. The lighting control system of claim 1, wherein the transceiver is a radio transceiver having an antenna.

3. The lighting control system of claim 2, further comprising an interface computer that communicates with the radio transceiver over a wireless link.

4. The lighting control system of claim 2, further comprising a sensor that communicates with the radio transceiver over a wireless link.

5. The lighting control system of claim 4, wherein the sensor is a motion sensor.

6. The lighting control system of claim 4, wherein the sensor is a light harvesting sensor.

7. The lighting control system of claim 1, wherein the dimming ballast further includes a diagnostics device, and wherein the diagnostics device sends a signal to the transceiver through the ballast interface cable.

8. The lighting control system of claim 1, wherein the first plug comprises an RJ 11 plug.

9. The lighting control system of claim 1, wherein the dimming ballast provides a diagnostic signal to the transceiver.

10. The lighting control system of claim 1, further comprising a binary switch connected to the data processing unit.

11. The lighting control system of claim 1, wherein the control signal corresponds to an on signal that gets applied to the first pin of the first plug.

12. The lighting control system of claim 1, wherein the control signal corresponds to a dimmer voltage that gets applied to the fourth pin of the first plug.

13. A lighting control system, comprising:

a sensor;

a power interface connected to the sensor by an interface cable; and

a ballast connected to the power interface by a second interface cable having an interface plug disposed at an end of the second interface cable, the interface plug including a first pin configured to provide an on/off signal from the sensor to the ballast, a second pin configured to provide a ground signal from the power inter-

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face to the ballast, a third pin configured to provide a voltage to power the ballast from the power interface, and a fourth pin configured to provide a dimmer voltage signal from the sensor to the ballast; wherein the power interface is configured to provide, over the interface cable, a voltage to power the sensor, and wherein the sensor is configured to provide, over the interface cable, an on/off signal and dimming signal to the ballast; wherein the power interface is further configured to relay, using the interface cable, the on/off and dimming signals to a second power interface.

14. The lighting system of claim **13**, wherein the sensor is a light harvesting sensor.

15. The lighting system of claim **13**, wherein the sensor is a motion sensor.

16. The lighting control system of claim **13**, wherein the interface plug comprises a RJ11 plug.

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17. The lighting control system of claim **13**, the power interface further comprising:

a power converter;

a power switch; and

a jack connected to the power converter, the power switch, and the interface plug, the jack configured to conduct signals over the first, second, third, and fourth pins of the interface plug, the first pin operably connected to the power switch and the third pin operably connected to the power converter.

18. The lighting control system of claim **13**, wherein the interface cable is connected to a 'Y' combiner that is in communication with the sensor and that relays the on/off and dimming signals to the second power interface.

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