US012389503B2

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

(10) **Patent No.: US 12,389,503 B2**
(45) **Date of Patent: *Aug. 12, 2025**

(54) **HUMAN-CENTRIC LIGHTING CONTROL**

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

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **18/418,823**

(22) Filed: **Jan. 22, 2024**

(65) **Prior Publication Data**

US 2024/0163989 A1 May 16, 2024

Related U.S. Application Data

(63) Continuation of application No. 17/745,602, filed on May 16, 2022, now Pat. No. 11,985,741, which is a continuation-in-part of application No. 17/302,973, filed on May 17, 2021, now Pat. No. 12,035,430.

(60) Provisional application No. 63/026,304, filed on May 18, 2020.

(51) **Int. Cl.**

H05B 45/20	(2020.01)
H05B 47/16	(2020.01)

(52) **U.S. Cl.**
CPC ***H05B 45/20*** (2020.01); ***H05B 47/16*** (2020.01)

(58) **Field of Classification Search**
None
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

7,348,949	B2	3/2008	Lee et al.
7,687,753	B2	3/2010	Ashdown
8,299,987	B2	10/2012	Neudorf et al.

(Continued)

FOREIGN PATENT DOCUMENTS

CA	2913239	A1	12/2014
WO	2010031169	A1	3/2010

(Continued)

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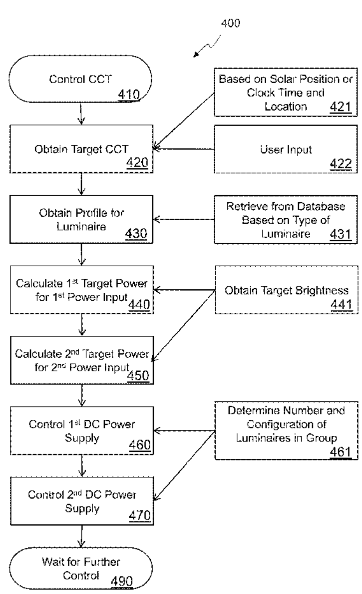
(74) *Attorney, Agent, or Firm* — Young's Patent Services; Bruce A.. Young

(57) **ABSTRACT**

A correlated color temperature (CCT) of one or more luminaires is controlled by obtaining a target CCT for the one or more luminaires and obtaining a first profile associated with a first luminaire of the one or more luminaires. A first target power for a first direct-current (DC) power input of the first luminaire and a second target power for a second DC power input of the first luminaire are calculated based on the target CCT and the first profile so that the first target power and the second target power drive the first luminaire to emit light at the target CCT. A first DC power supply is controlled to deliver the first target power to the first DC power input of the first luminaire and a second DC power supply is controlled to deliver the second target power to the second DC power input of the first luminaire.

20 Claims, 16 Drawing Sheets



(56) **References Cited**

U.S. PATENT DOCUMENTS

8,330,373	B2	12/2012	Ramer et al.
8,337,031	B2	12/2012	Wegh et al.
8,517,550	B2	8/2013	Ramer et al.
8,525,446	B2	9/2013	Tikkanen et al.
8,866,414	B2	10/2014	Maxik et al.
8,926,133	B2	1/2015	Booth
8,957,601	B2	2/2015	Tikkanen et al.
9,039,230	B2	5/2015	Crimi et al.
9,041,379	B2	5/2015	Lyons
9,049,759	B2	6/2015	Tikkanen et al.
9,055,622	B2	6/2015	Aldrich et al.
9,078,310	B2	7/2015	Tikkanen et al.
9,320,093	B2	4/2016	Tikkanen et al.
9,410,664	B2	8/2016	Krames et al.
9,433,053	B2	8/2016	Neudorf
9,591,713	B2	3/2017	Tikkanen et al.
9,662,409	B2	5/2017	Rains, Jr. et al.
9,775,207	B2	9/2017	Tikkanen et al.
9,942,954	B2	4/2018	Neudorf et al.
10,045,421	B2	8/2018	Tikkanen et al.
10,076,016	B2	9/2018	Tikkanen et al.
10,187,946	B2	1/2019	Tikkanen et al.
10,237,945	B2	3/2019	Sooch et al.
10,299,441	B2	5/2019	Elmpt et al.
10,362,655	B2	7/2019	Heim et al.
10,368,811	B1	8/2019	Bajaj et al.
10,582,596	B2	3/2020	Sooch et al.
10,621,836	B2	4/2020	Sooch et al.
10,757,791	B1	8/2020	Jonsson
12,035,430	B2 *	7/2024	Upton H05B 45/20
2006/0125770	A1	6/2006	Kao et al.
2008/0251690	A1	10/2008	Keiper et al.
2011/0204820	A1	8/2011	Tikkanen et al.
2012/0119658	A1	5/2012	McDaniel
2013/0018522	A1	1/2013	Nuhfer et al.
2013/0093362	A1	4/2013	Edwards
2013/0218030	A1	8/2013	Barroso et al.
2016/0128144	A1	5/2016	Tikkanen et al.
2016/0158486	A1	6/2016	Colbaugh et al.
2016/0227616	A1	8/2016	Lee
2016/0262221	A1	9/2016	Nishioka et al.
2017/0025028	A1	1/2017	Hrushesky
2017/0105265	A1	4/2017	Sadwick
2017/0127497	A1	5/2017	Baek et al.
2017/0132946	A1	5/2017	Kinnunen et al.
2017/0332462	A1	11/2017	Tikkanen
2018/0318602	A1	11/2018	Ciccarelli et al.
2019/0183415	A1	6/2019	Rytky et al.
2019/0216391	A1	7/2019	Kenyon et al.
2019/0279482	A1	9/2019	Kaplan et al.
2020/0068680	A1	2/2020	Neudorf et al.

FOREIGN PATENT DOCUMENTS

WO	2016067028	A2	5/2016
WO	2018220087	A1	12/2018
WO	2019141904	A1	7/2019
WO	2020082178	A1	4/2020

* cited by examiner

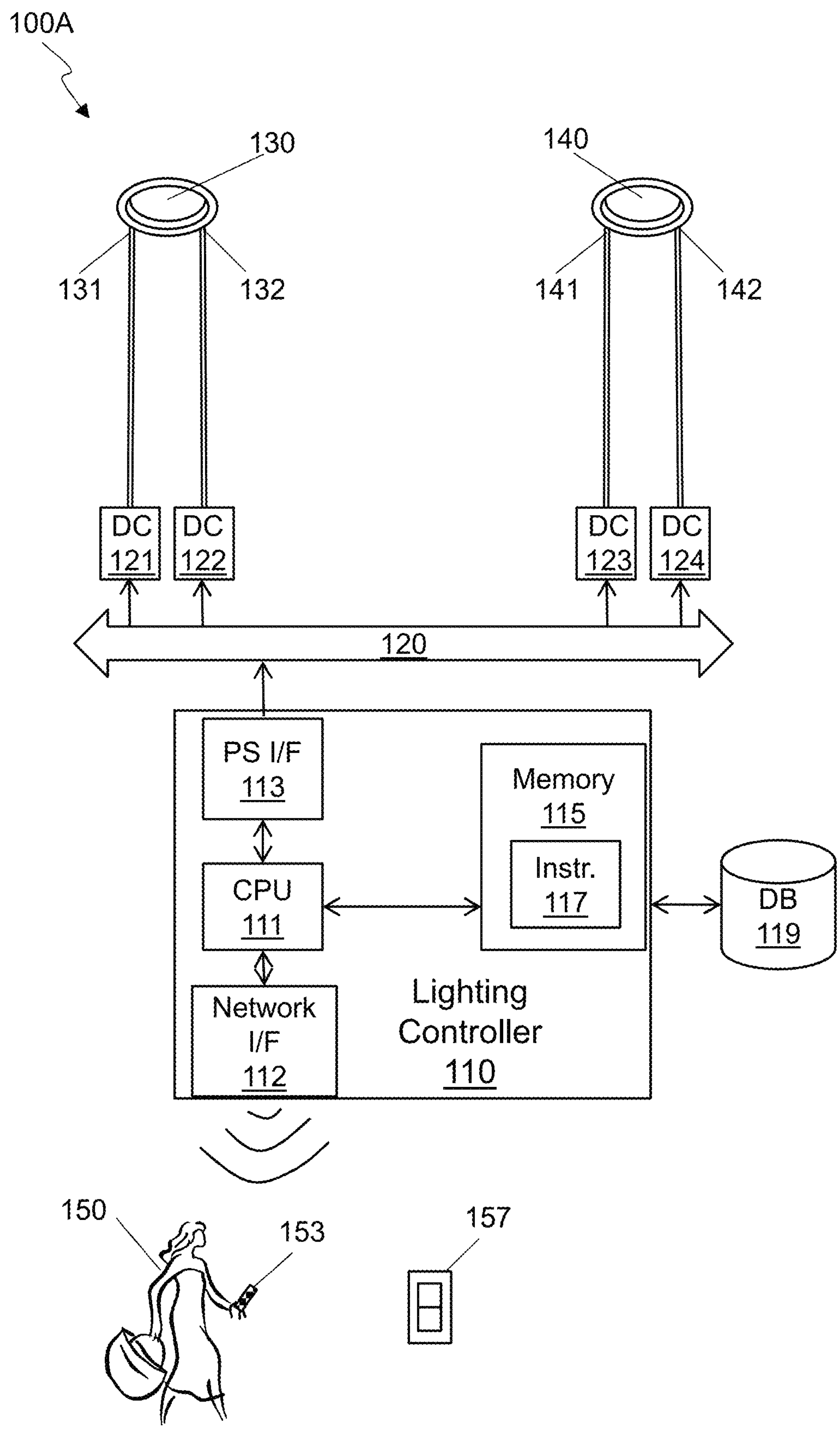

100A
130
140
131
132
141
142
DC 121
DC 122
DC 123
DC 124
120
PS I/F 113
CPU 111
Network I/F 112
Memory 115
Instr. 117
DB 119
Lighting Controller 110
150
153
157

FIG. 1A

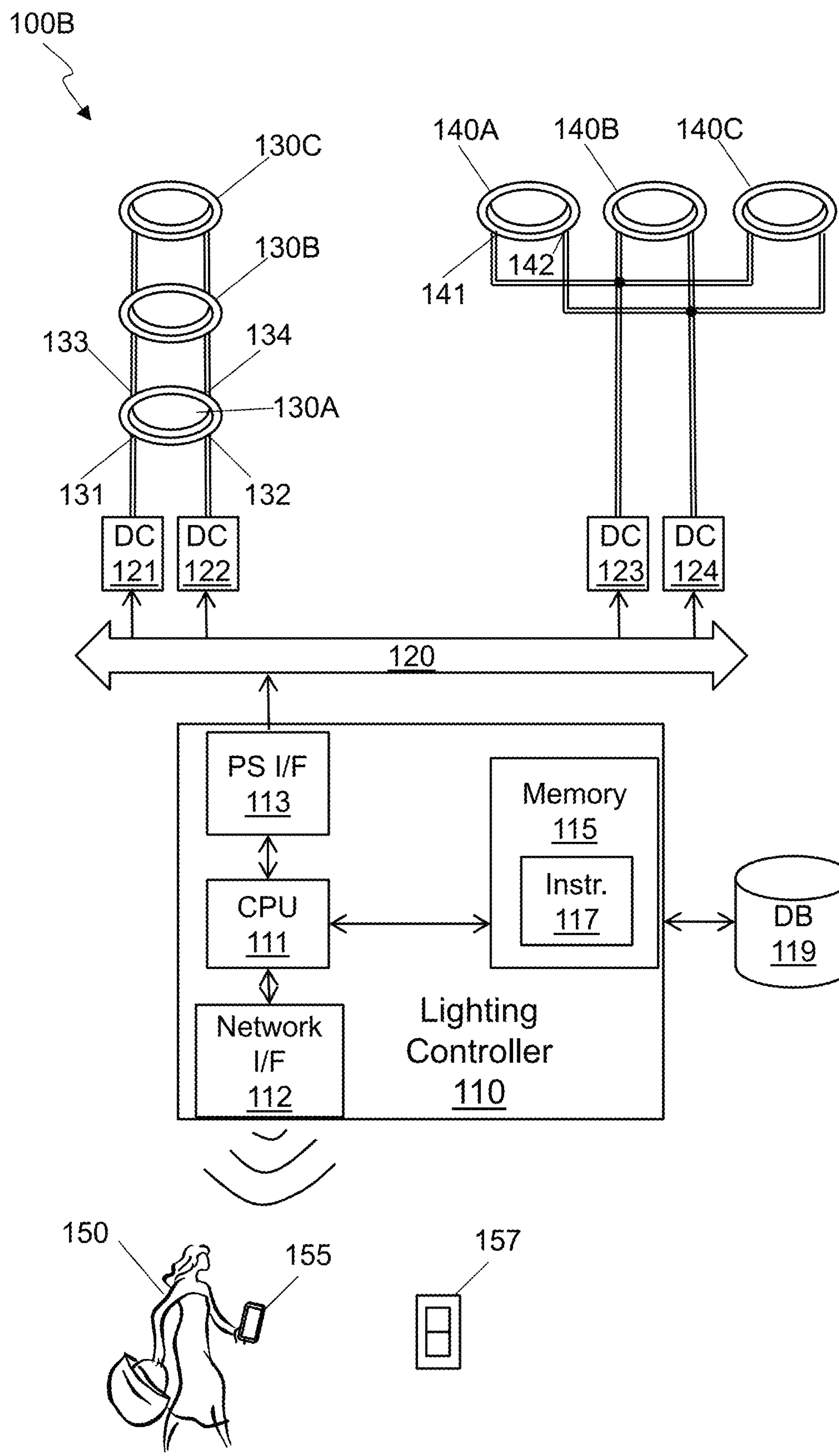

100B
130C
130B
133
134
130A
131
132
140A
140B
140C
141
142
DC 121
DC 122
DC 123
DC 124
120
PS I/F 113
CPU 111
Network I/F 112
Memory 115
Instr. 117
DB 119
Lighting Controller 110
150
155
157

FIG. 1B

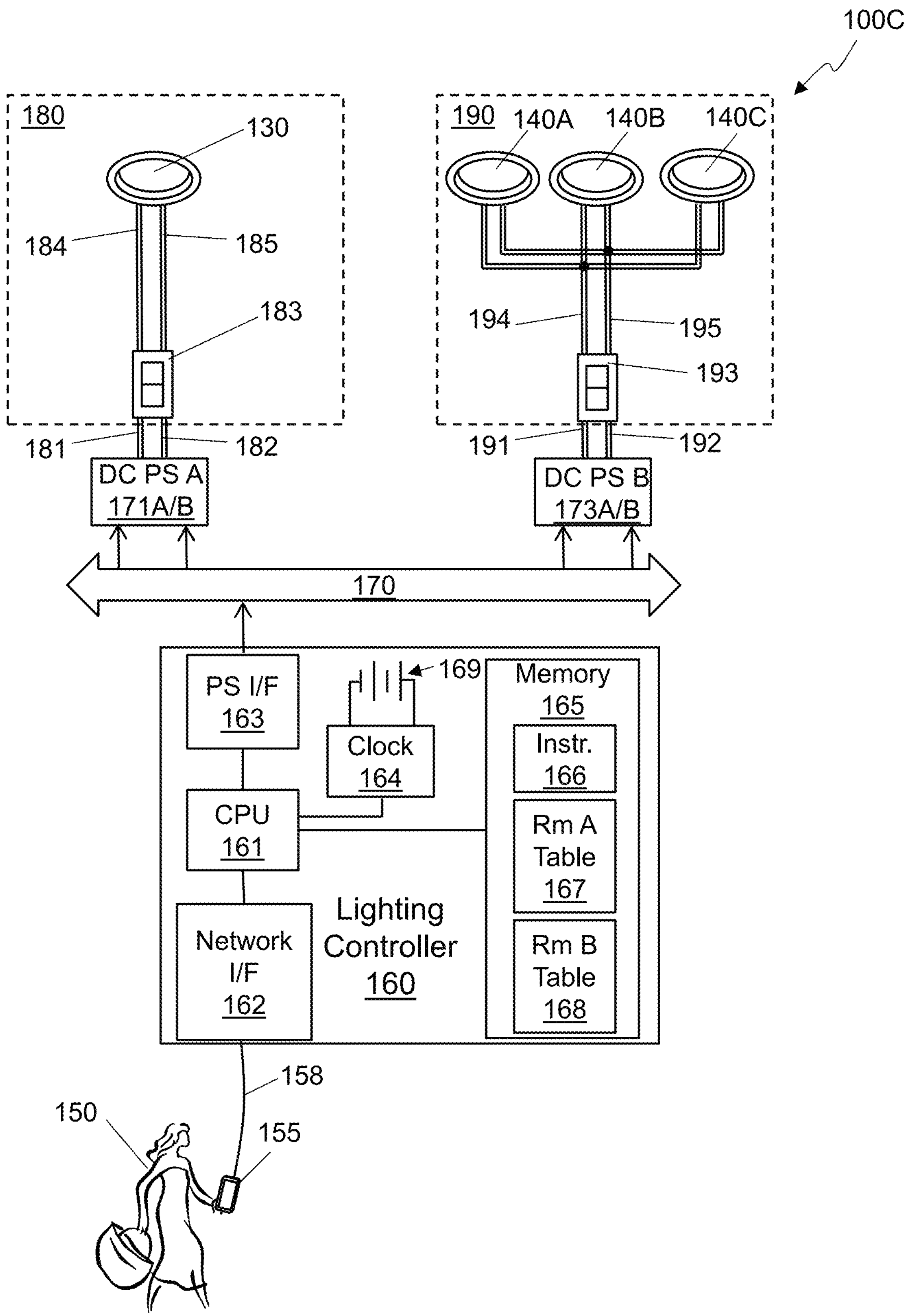

100C
180
130
184
185
183
181
182
DC PS A
171A/B
190
140A
140B
140C
194
195
193
191
192
DC PS B
173A/B
170
PS I/F
163
169
Clock
164
Memory
165
Instr.
166
CPU
161
Rm A
Table
167
Network
I/F
162
Lighting
Controller
160
Rm B
Table
168
158
150
155

FIG. 1C

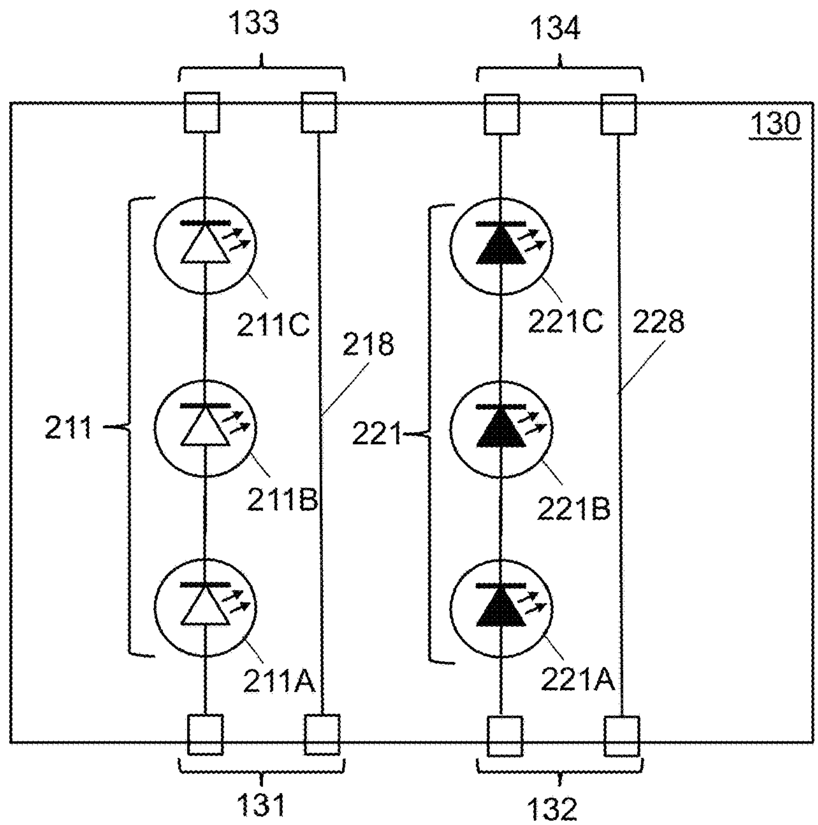

133
134
130
211C
218
221C
228
211
221
211B
221B
211A
221A
131
132

FIG. 2A

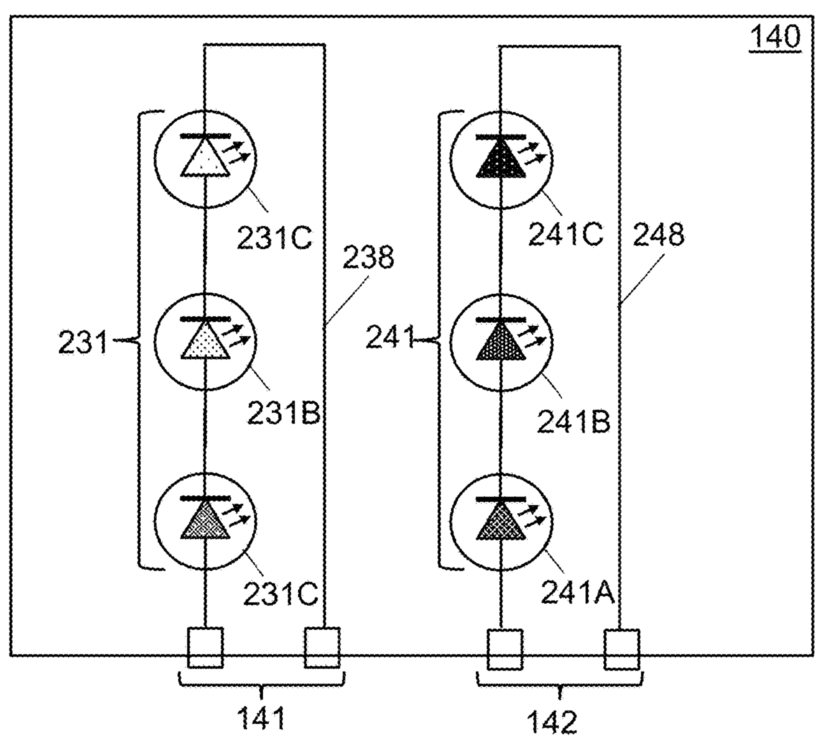

140
231C
238
241C
248
231
241
231B
241B
231C
241A
141
142

FIG. 2B

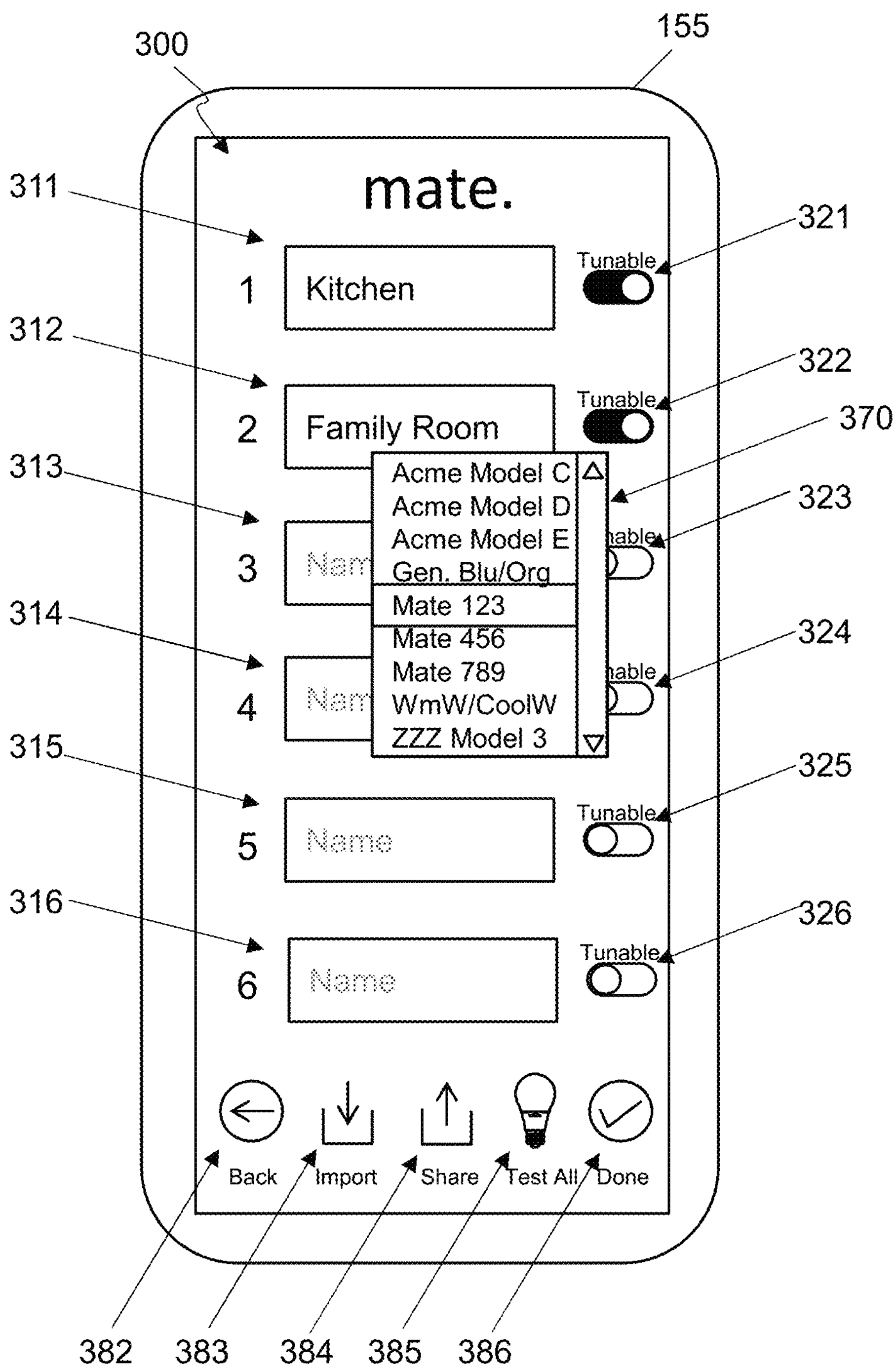
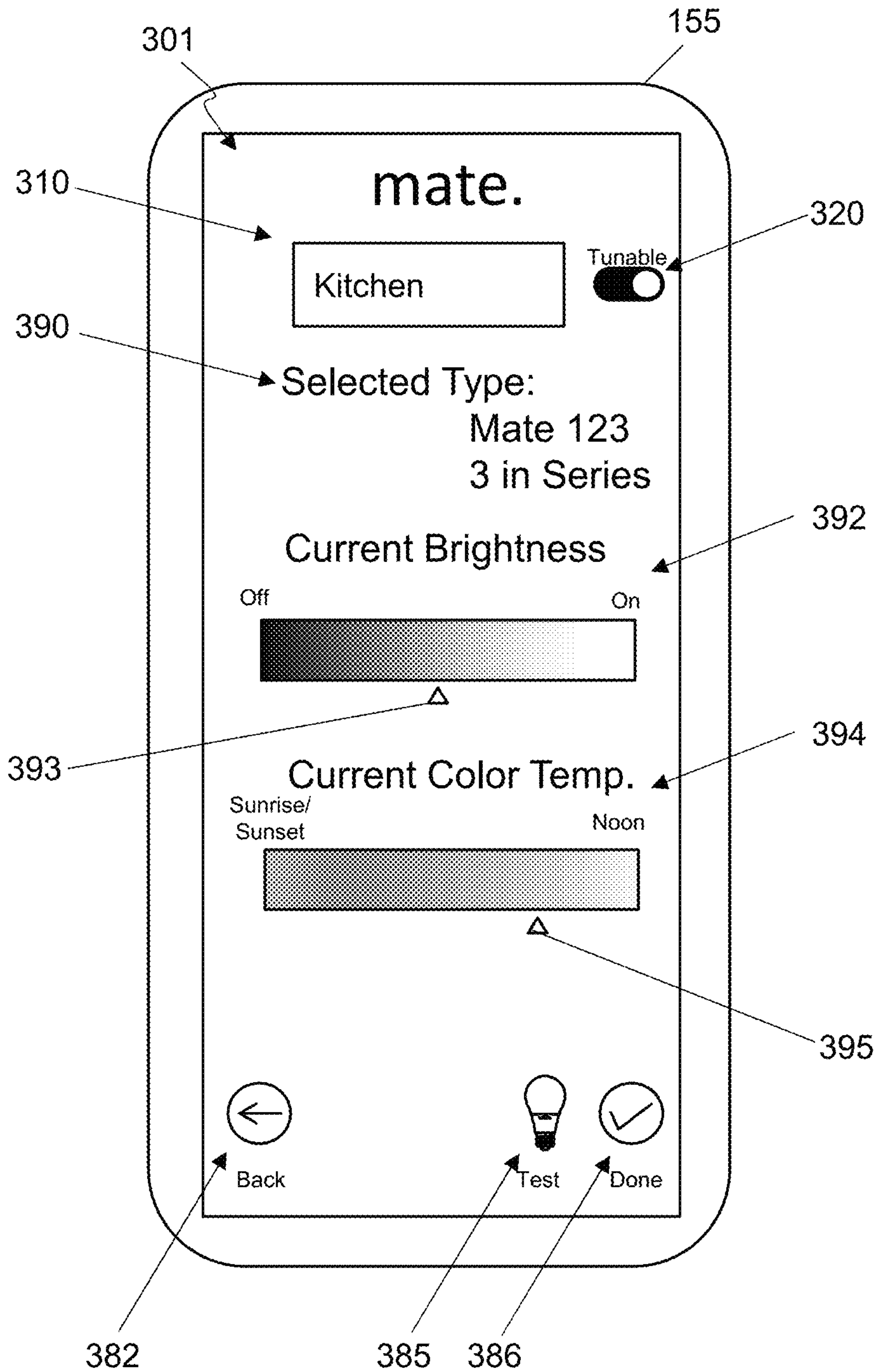

300
155
mate.
311
312
313
314
315
316
321
322
323
324
325
326
370
1
Kitchen
2
Family Room
3
4
5
6
Name
Name
Tunable
Tunable
Tunable
Tunable
Acme Model C
Acme Model D
Acme Model E
Gen. Blu/Org
Mate 123
Mate 456
Mate 789
WmW/CoolW
ZZZ Model 3
Back
Import
Share
Test All
Done
382
383
384
385
386

FIG. 3A



155
301
310
mate.
Kitchen
Tunable
320
390
Selected Type:
Mate 123
3 in Series
392
Current Brightness
Off
On
393
394
Current Color Temp.
Sunrise/
Sunset
Noon
395
Back
Test
Done
382
385
386

FIG. 3B

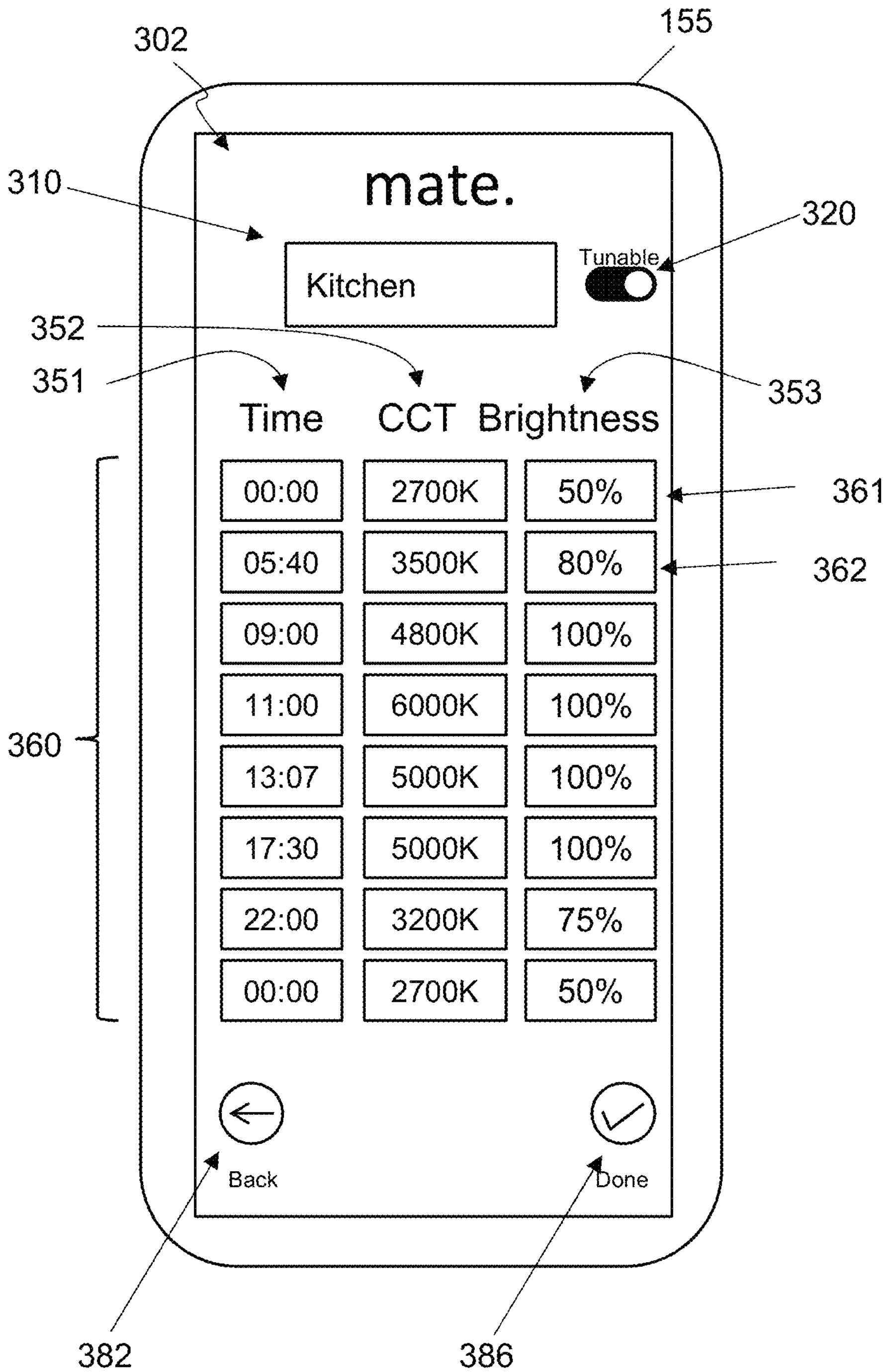

302
155
310
mate.
320
Tunable
Kitchen
352
351
353
Time
CCT
Brightness
00:00
2700K
50%
361
05:40
3500K
80%
362
09:00
4800K
100%
11:00
6000K
100%
360
13:07
5000K
100%
17:30
5000K
100%
22:00
3200K
75%
00:00
2700K
50%
Back
Done
382
386

FIG. 3C

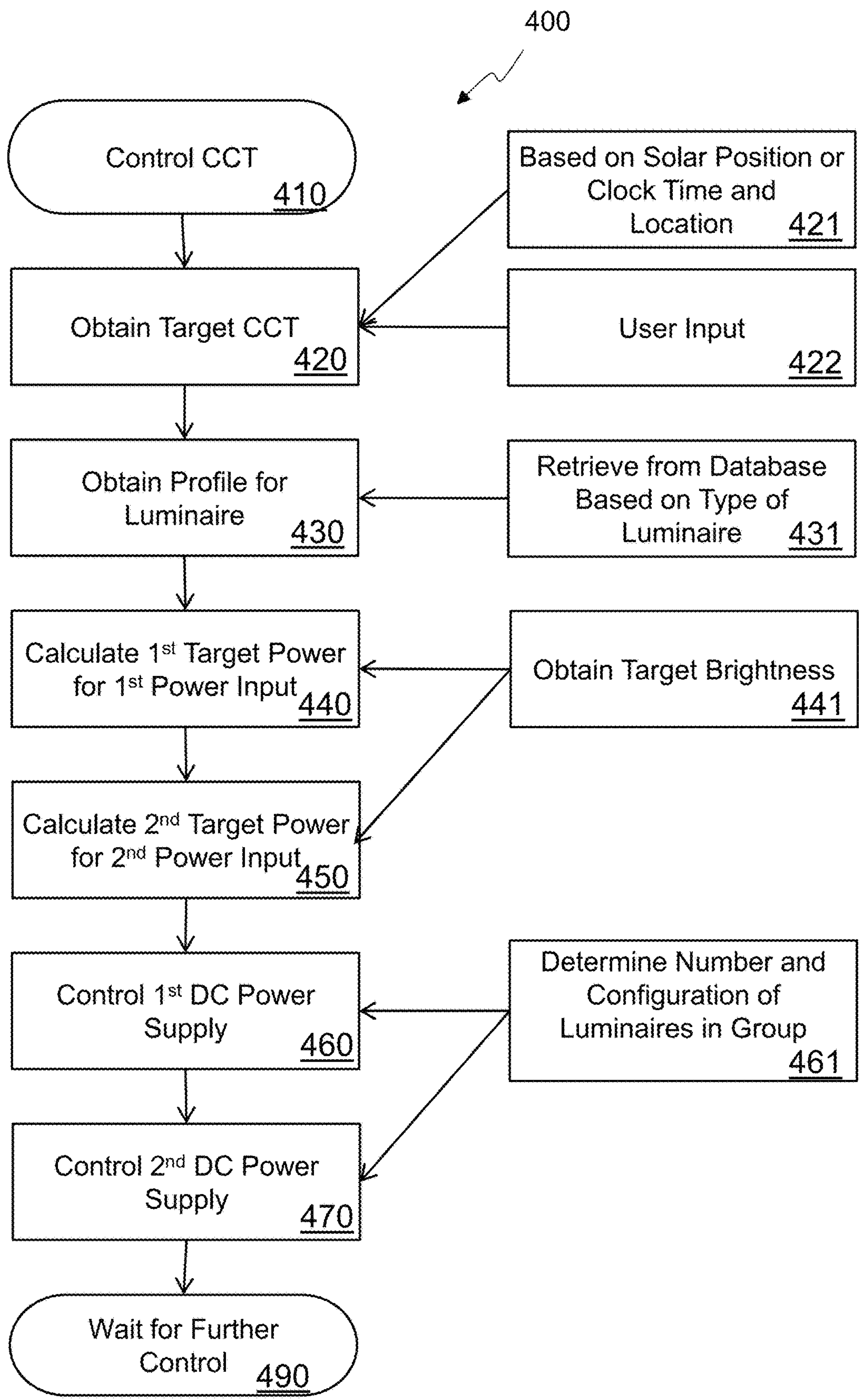

400
Control CCT 410
Obtain Target CCT 420
Based on Solar Position or Clock Time and Location 421
User Input 422
Obtain Profile for Luminaire 430
Retrieve from Database Based on Type of Luminaire 431
Calculate 1st Target Power for 1st Power Input 440
Obtain Target Brightness 441
Calculate 2nd Target Power for 2nd Power Input 450
Control 1st DC Power Supply 460
Determine Number and Configuration of Luminaires in Group 461
Control 2nd DC Power Supply 470
Wait for Further Control 490

FIG. 4

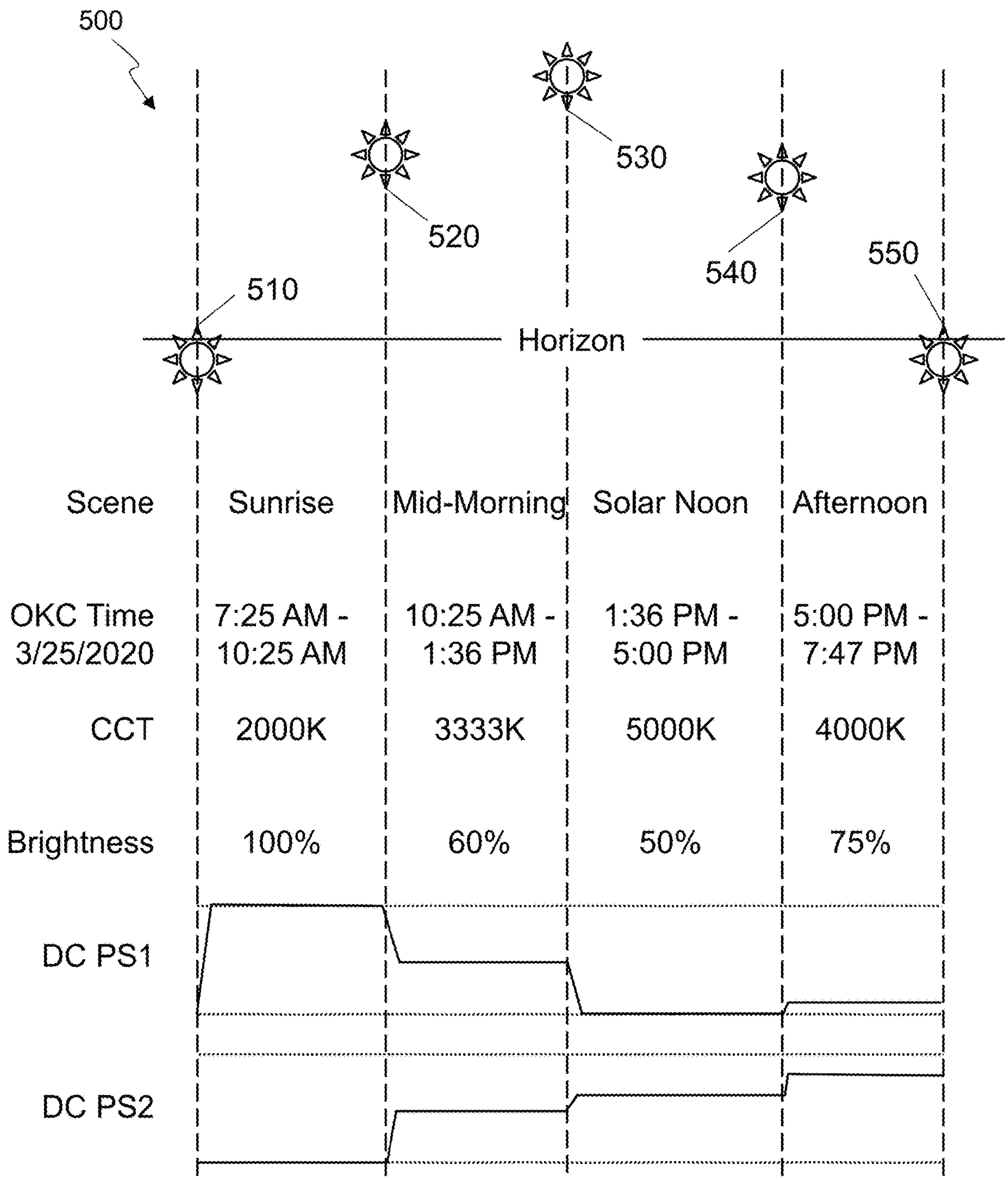
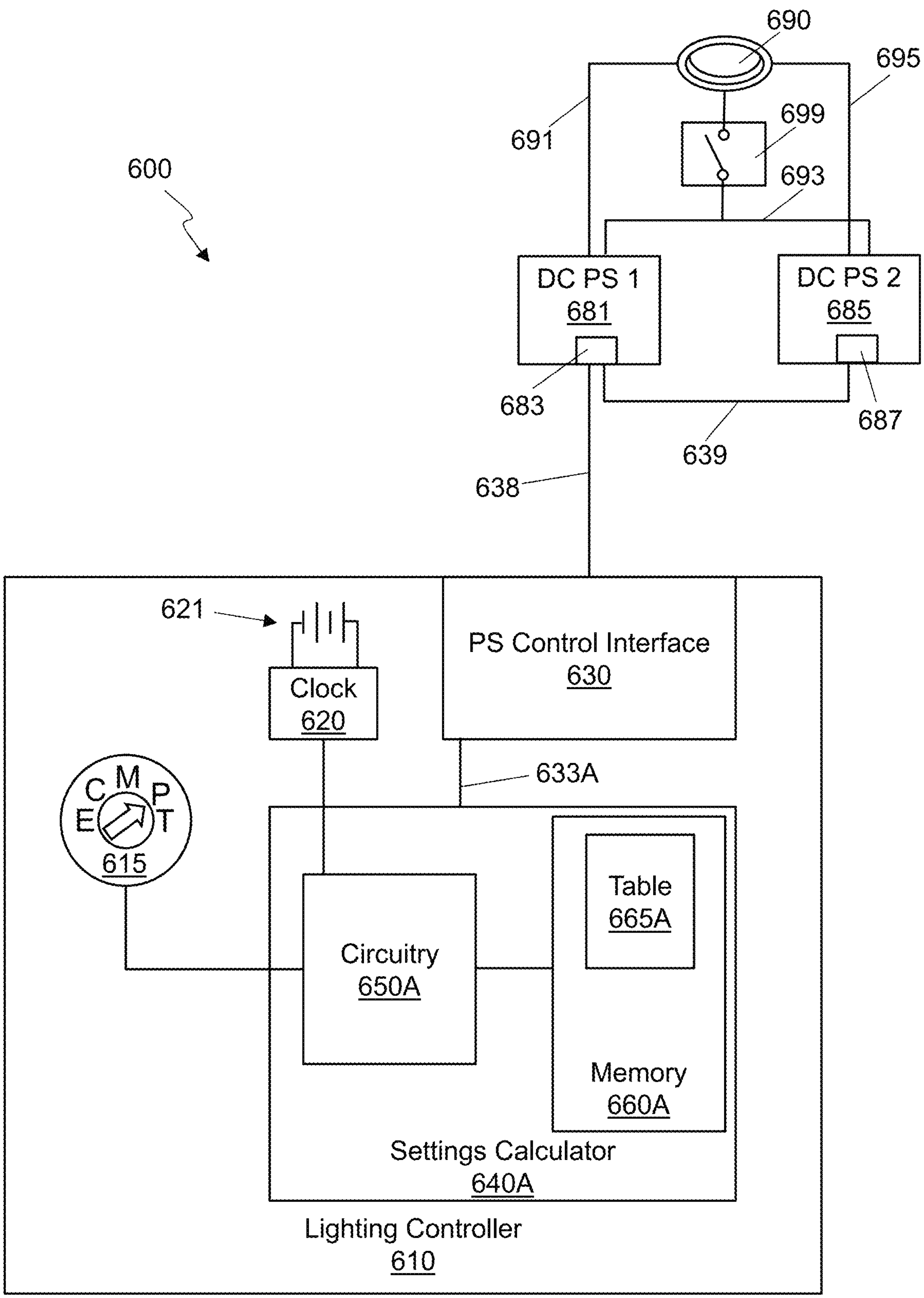

500
510
520
530
540
550
Horizon
Scene
Sunrise
Mid-Morning
Solar Noon
Afternoon
OKC Time
3/25/2020
7:25 AM -
10:25 AM
10:25 AM -
1:36 PM
1:36 PM -
5:00 PM
5:00 PM -
7:47 PM
CCT
2000K
3333K
5000K
4000K
Brightness
100%
60%
50%
75%
DC PS1
DC PS2

FIG. 5



690
695
691
699
600
693
DC PS 1
681
DC PS 2
685
683
687
639
638
621
PS Control Interface
630
Clock
620
633A
C
M
P
E
T
615
Table
665A
Circuitry
650A
Memory
660A
Settings Calculator
640A
Lighting Controller
610

FIG. 6A

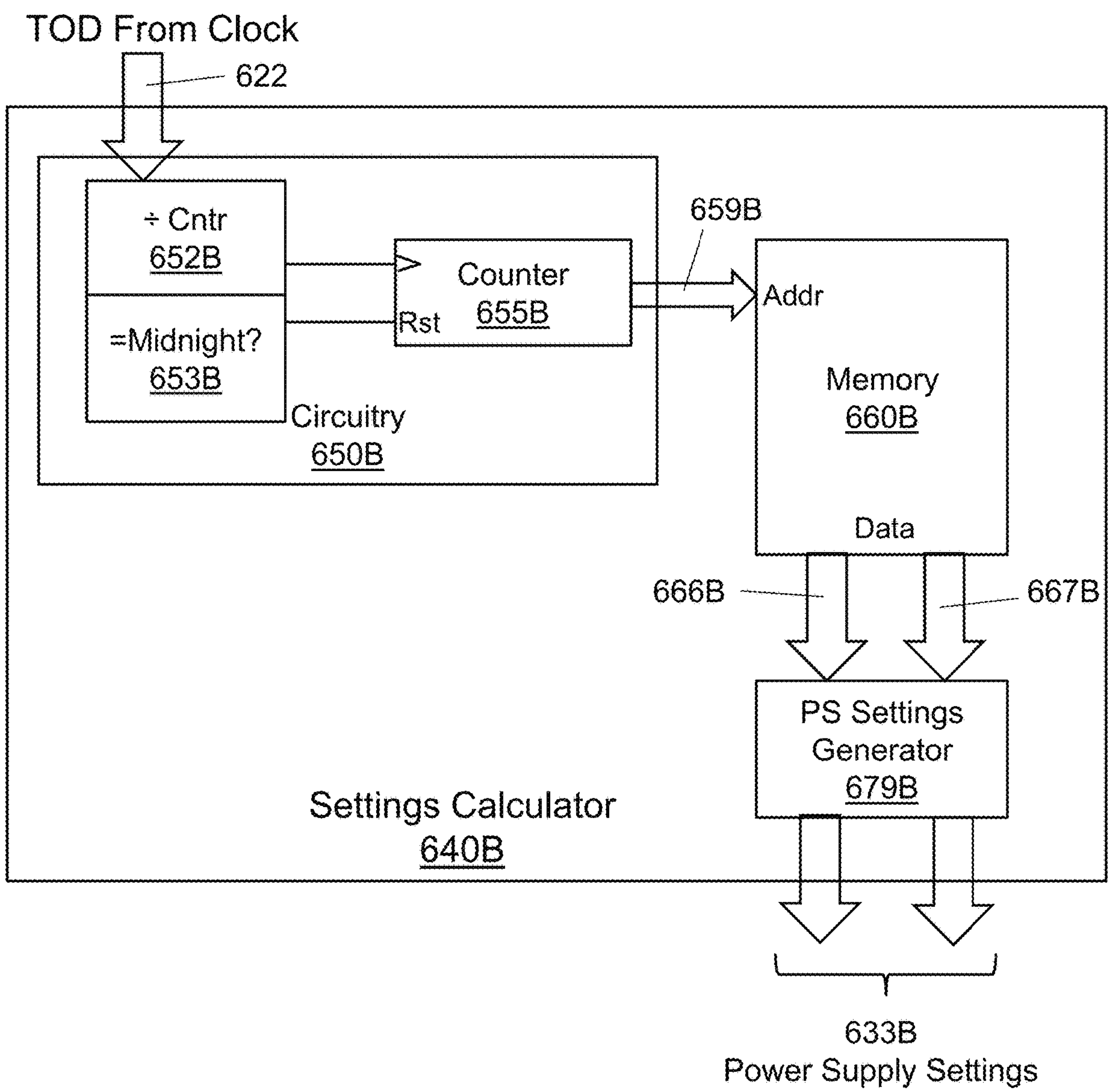

TOD From Clock
622
÷ Cntr
652B
=Midnight?
653B
Counter
655B
Rst
Circuitry
650B
659B
Addr
Memory
660B
Data
666B
667B
PS Settings
Generator
679B
Settings Calculator
640B
633B
Power Supply Settings

FIG. 6B

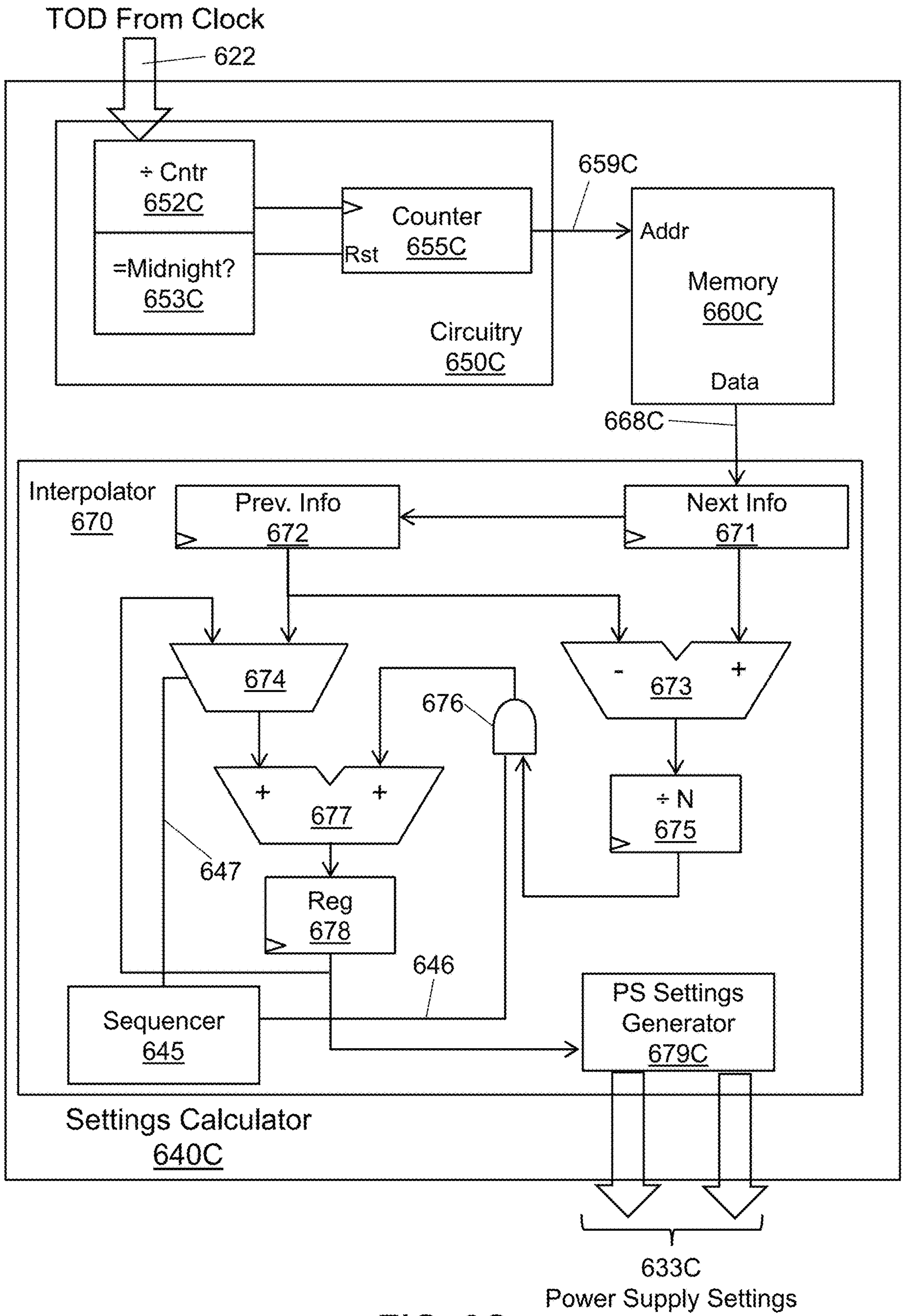

TOD From Clock
622
÷ Cntr
652C
=Midnight?
653C
Counter
655C
Rst
Circuitry
650C
659C
Addr
Memory
660C
Data
668C
Interpolator
670
Prev. Info
672
Next Info
671
674
673
676
677
÷ N
675
647
Reg
678
646
Sequencer
645
PS Settings
Generator
679C
Settings Calculator
640C
633C
Power Supply Settings

FIG. 6C

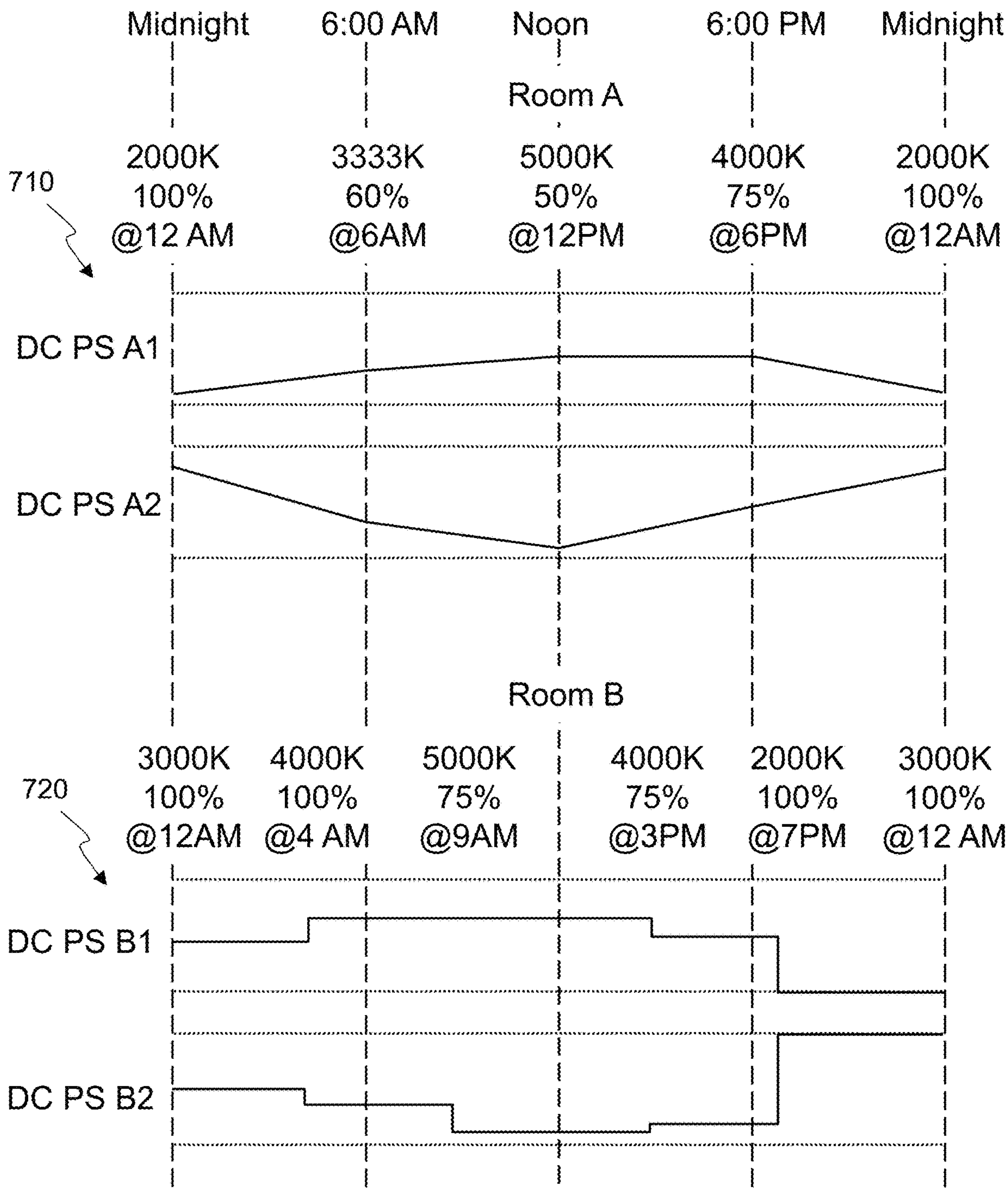

Midnight
6:00 AM
Noon
6:00 PM
Midnight
Room A
2000K 100% @12 AM
3333K 60% @6AM
5000K 50% @12PM
4000K 75% @6PM
2000K 100% @12AM
710
DC PS A1
DC PS A2
Room B
3000K 100% @12AM
4000K 100% @4 AM
5000K 75% @9AM
4000K 75% @3PM
2000K 100% @7PM
3000K 100% @12 AM
720
DC PS B1
DC PS B2

FIG. 7A

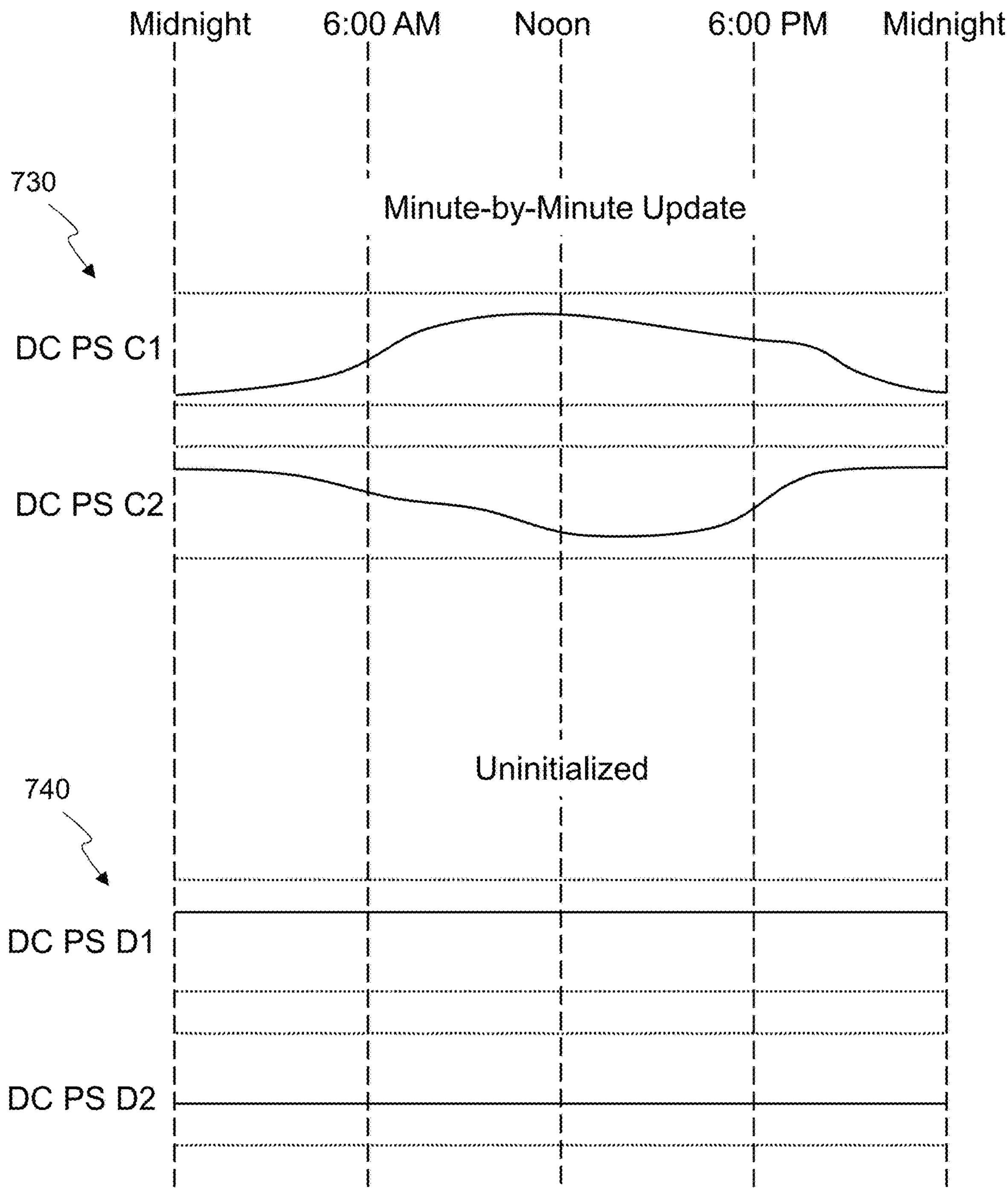

Midnight
6:00 AM
Noon
6:00 PM
Midnight
730
Minute-by-Minute Update
DC PS C1
DC PS C2
Uninitialized
740
DC PS D1
DC PS D2

FIG. 7B

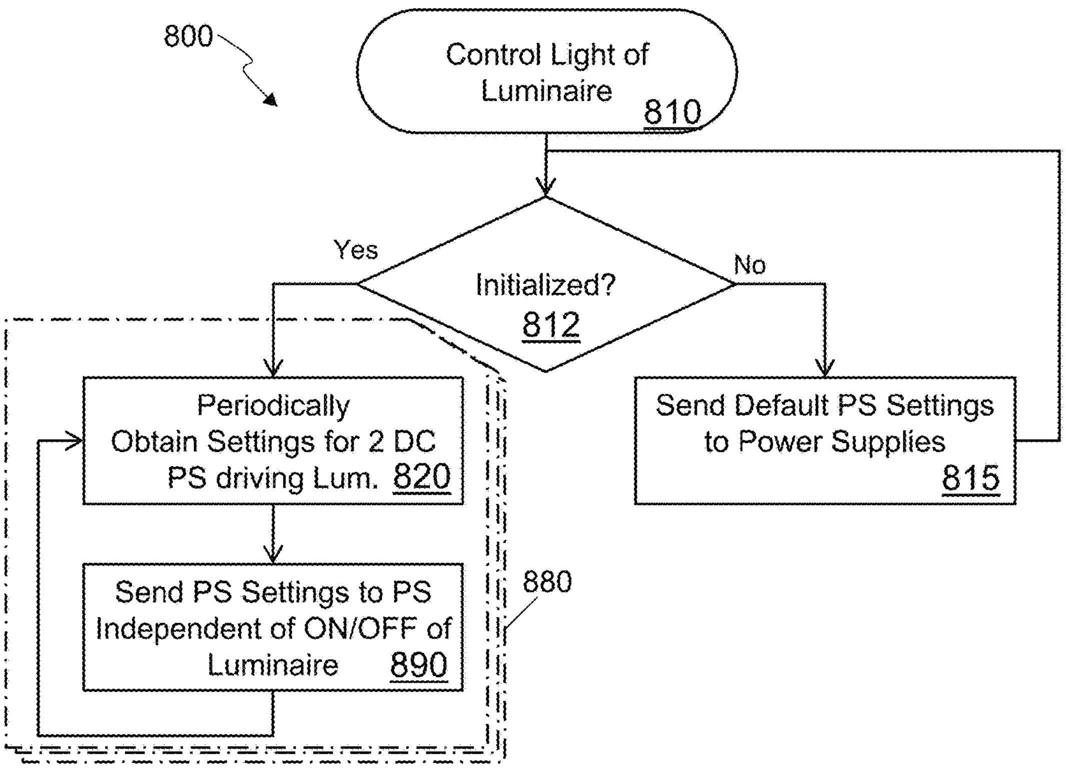

800
Control Light of Luminaire 810
Initialized? 812
Yes
No
Periodically Obtain Settings for 2 DC PS driving Lum. 820
Send PS Settings to PS Independent of ON/OFF of Luminaire 890
Send Default PS Settings to Power Supplies 815
880

FIG. 8A

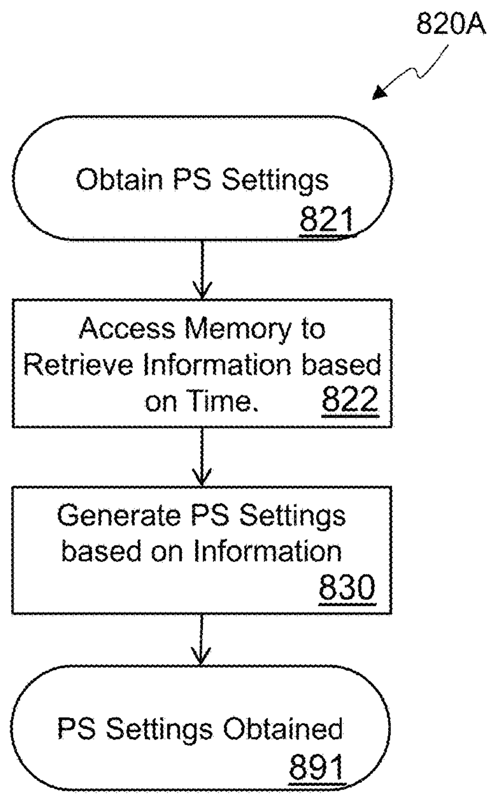

820A
Obtain PS Settings 821
Access Memory to Retrieve Information based on Time. 822
Generate PS Settings based on Information 830
PS Settings Obtained 891

FIG. 8B

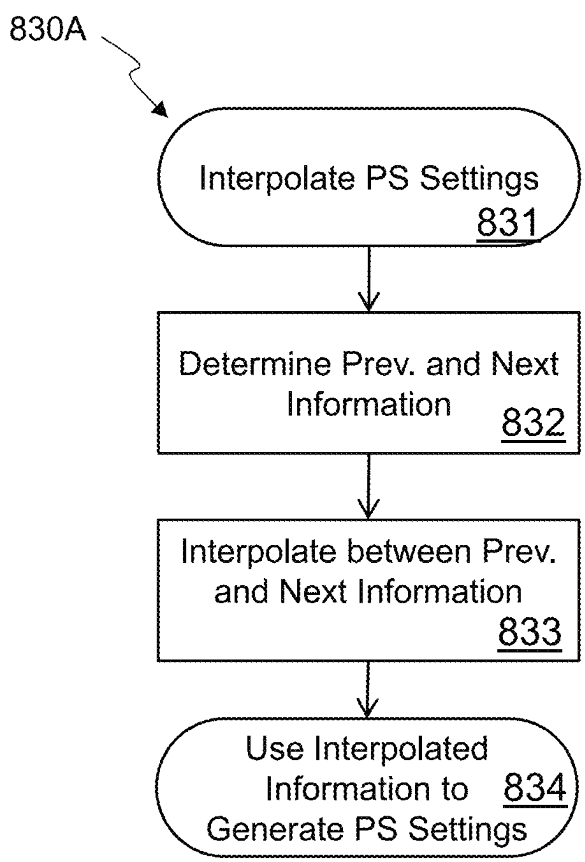

830A
Interpolate PS Settings 831
Determine Prev. and Next Information 832
Interpolate between Prev. and Next Information 833
Use Interpolated Information to Generate PS Settings 834

FIG. 8C

HUMAN-CENTRIC LIGHTING CONTROL

CROSS-REFERENCE TO RELATED APPLICATIONS

This application a continuation of U.S. patent application Ser. No. 17/745,602, filed on May 16, 2022, and entitled "HUMAN-CENTRIC LIGHTING CONTROLLER," which is a continuation-in-part of U.S. patent application Ser. No. 17/302,973, filed on May 17, 2021, and entitled "CENTRALLY-CONTROLLED TUNABLE LIGHTING," which claims the benefit of U.S. Provisional Application 63/026,304 filed May 18, 2020, and entitled "CENTRALLY CONTROLLED SYSTEMS AND METHODS FOR DIRECT-CURRENT TUNABLE LIGHTING," all three of which are hereby incorporated by reference in their entirety herein for any and all purposes.

TECHNICAL FIELD

The present subject matter relates to centrally-controlled tunable lighting. More particularly the disclosure relates to central control of direct-current (DC) tunable solid-state lighting systems configured to set indoor lighting for particular times of the solar day.

BACKGROUND

Light sources may be classified by the color appearance of the light wavelengths they produce, which may be referred to as the correlated color temperature (or simply, color temperature) of the light wavelengths. The correlated color temperature (CCT) is a measure of how "cool" or "warm" the light wavelengths appear to the human eye and may be measured in degrees Kelvin (K, a unit of thermodynamic temperature, equal in magnitude to a degree Celsius but starting at absolute zero) or in micro reciprocal degrees. A "micro reciprocal degree", commonly referred to as a mired (M), is a unit of measurement used to express color temperature based on the following formula: M=1,000,000/(Color Temperature in Kelvins), so 100 M=10000K, 200 M=5000K, 300 M=3333K, 400 M=2500K, and 500 M=2000K. Note that because there is a direct reciprocal relationship between K and M, either one can be used interchangeably to describe a light source.

The CCT of a light source may be technically defined as the temperature of an ideal black-body radiator that radiates light of a color comparable to that of the light source. Typically, the cooler the light wavelengths appear, the higher the CCT or the lower the mired value. The warmer the light wavelengths appear, the lower the CCT or a higher mired value.

As the sun appears to move across the sky, the CCT of sunlight reaching a person on the Earth changes incrementally from a warm orange light at sunrise to a cool blue light at solar noon and back to a warm orange light at sunset. The time of day of these events changes depending on the day of the year and the location of the observer on the Earth. For example, on Mar. 25, 2020, the sunrise in Oklahoma City, Oklahoma, USA was at 7:25 AM. Central Daylight Savings Time (CDT), solar noon occurred at 1:36 PM. CDT, and the sunset was at 7:47 PM. CDT. As an example of the change in time of these events based on the day, on Apr. 13, 2020, the first light in Oklahoma City, Oklahoma, USA, was at 6:31 AM. CDT, sunrise was at 6:58 AM CDT, solar noon occurred at 1:30 PM CDT, and the sunset was at 8:02 PM CDT. This information can be determined for every day

based on calculation of the position of the sun and the Earth. The information may also be retrieved from one or more pre-calculated databases.

The changing CCT of daylight affects human circadian rhythms. The circadian system in animals and humans is near, but not exactly, 24-hours in cycle length, and must be reset daily to remain synchronized with external environmental time, a process known as entrainment. Entrainment is achieved in most mammals through regular exposure to contrast between light color and darkness.

Circadian rhythms control the sleep-wake cycle, affect alertness, and affect quality of sleep, among other physiological and behavioral factors. Exposure to light having a CCT differing from that of current daylight can have a negative impact on circadian rhythm, including changing the timing of the sleep-wake cycle, periods of alertness, and/or periods of drowsiness, for example. Further, exposure to certain wavelengths of light may be beneficial during daylight hours because the wavelengths may boost attention, reaction times, and mood, but may be detrimental and disruptive to sleep at night. Exposure of people to light at night can shift circadian rhythms and suppress the secretion of melatonin. Further, research shows that unbalanced circadian rhythms with shortened or disrupted sleep cycles may contribute to the causation of disease, by lessoning the time for the body to heal itself.

Currently, most common commercially available artificial light sources emit light having a fixed CCT, are rated to output a set brightness in lumens, and to use a particular amount of power in Watts (W). For example, a light fixture (or luminaire) may have a light emitting diode (LED) that produces light at 2700K (a warm, or orangish color), at a light output of 1550 lumens, and be rated to use 18 W of power when connected to an alternating current (AC) 120 V power source. However, a single-color light output greatly limits the lighting effects that can be accomplished and does not match the changing colors of daylight from the sun.

Some "smart" single-point lighting fixtures are available that include multiple light emitting diodes that have different colors of light output and a computer chip within the fixture that can control which LEDs receive power, and therefore, which LEDs produce light. Typically, these smart single-point lighting fixtures must be programmed individually. This individual programming, when multiplied across all smart single-point lighting fixtures in a structure (sometimes hundreds of fixtures), requires a significant amount of time and knowledge. Some smart single-point lighting fixtures may be programmed using a wireless retrofit connection, in that the smart single-point lighting fixtures are used in electrical sockets wired for AC and have wireless capability within the smart single-point lighting fixtures such that they can be programmed remotely, or remotely as a set of fixtures. However, a computer chip is still required within each individual smart single-point lighting fixture.

Additionally, each of the smart single-point lighting fixtures is electrically connected to an AC electrical power source. The AC power is converted to direct current (DC) power to drive the actual LEDs which results in excess heat that must be dissipated by the lighting fixture and can result in the premature failure of the smart single-point lighting fixture caused by failure of the computer chip through exposure to the heat. Often the computer chip fails in this way well before the LEDs fail. For example, the computer chip may fail while the LEDs still have one third to one half of its predicted life. Further, because of requirements for AC to DC electrical power conversion to power the smart single-point lighting fixtures, the smart single-point lighting fixtures are power inefficient up to 70% and thus multiple breakers may be required in an electrical panel to contain all of the electrical wiring for a building having smart single-point lighting fixtures. Also, the use of AC electrical power means that the amount of, or variation in, power delivered to the LEDs must be controlled at the fixture itself, not from a central location.

Systems also currently exist to control lighting systems from a DMX controller board, which is a computer circuit board or computer processor programmed in compliance with the Digital Multiplex (DMX) standard for digital communication networks, which is entitled "Entertainment Technology—USITT DMX512-A—Asynchronous Serial Digital Data Transmission Standard for Controlling Lighting Equipment and Accessories." The standard was originally developed in 1986 with the most recent revision approved by the American National Standards Institute (ANSI) in 2008 ("E1.11-2008, USITT DMX512-A"), but will be referred to herein as DMX, and it is understood that future revisions are contemplated. And while DMX may allow for sending control information to lighting fixtures, it does not address providing power, and thus many of the issues related to AC-powered single-point lighting fixtures, such as excess heat generation, may still be present in lighting systems using DMX.

For example, a DMX controller board may be used to control up to 512 functions (referred to as "channels") on a single network bus wired to an output connection of the DMX controller board. Each lighting fixture may include multiple functions (i.e., channels). For example, a lighting fixture including three light emitting diodes, each having a different color output, may have three channels (that is, one for each light emitting diode).

Traditionally, programming lighting systems using DMX has been complicated, difficult, and time-consuming since the devices are programmed at the DMX controller board and/or at the light fixtures. The programming may be done in an analog manner (typically using a series of switches and buttons) or remotely. Such programming is usually done by audio-visual technicians having specific training in such systems. The programming is typically done after an electrician has installed the lighting fixtures and so also requires additional personnel and time.

In addition, current lighting systems are programmed without regard for, and without using or considering, external data factors. For example, a smart single-point fixture may be set for a cool-light output starting at six in the morning, without regard to actual external daylight conditions. As another example, a series of lighting fixture effects may be programmed with no consideration to matching external sunlight changes. Additionally, traditional user interfaces require programming languages that have been complex and difficult for installers, such as trade electricians, to learn and to implement. Often, only specially trained installers are able to navigate the traditional programming interfaces.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings, which are incorporated in and constitute part of the specification, illustrate various embodiments. Together with the general description, the drawings serve to explain various principles. In the drawings:

FIG. **1**A shows a block diagram of an embodiment of a lighting system;

FIG. **1**B shows a block diagram of an embodiment of an expanded lighting system;

FIG. **1**C shows a block diagram of an alternative embodiment of a lighting system;

FIGS. **2**A and **2**B are schematic diagrams embodiments of luminaires suitable for use in the expanded lighting system of FIG. **1**B;

FIGS. **3**A, **3**B, and **3**C depict embodiments of graphical user interfaces on a mobile electronics device suitable for use with the lighting systems of FIGS. **1**A, **1**B and **1**C;

FIG. **4** is a flow chart of an embodiment of a method for controlling a correlated color temperature (CCT) of one or more luminaires;

FIG. **5** shows an example behavior of an embodiment of a lighting system through a day;

FIG. **6**A shows a block diagram of an alternative embodiment of a lighting system using an alternative embodiment of a lighting controller;

FIG. **6**B shows a block diagram of an embodiment of a settings calculator for use in a lighting controller;

FIG. **6**C shows a block diagram of an alternative embodiment of a settings calculator for use in a lighting controller;

FIGS. **7**A and **7**B show power supply output levels for several examples that could be generated from embodiments; and

FIGS. **8**A, **8**B, and **8**C show flow charts of aspects of an embodiment of a method for controlling a light characteristic of luminaire.

DETAILED DESCRIPTION

In the following detailed description, numerous specific details are set forth by way of examples in order to provide a thorough understanding of the relevant teachings. However, it should be apparent to those skilled in the art that the present teachings may be practiced without such details. In other instances, well known methods, procedures, and components have been described at a relatively high-level, without detail, in order to avoid unnecessarily obscuring aspects of the present concepts. A number of descriptive terms and phrases are used in describing the various embodiments of this disclosure. These descriptive terms and phrases are used to convey a generally agreed upon meaning to those skilled in the art unless a different definition is given in this specification. Some descriptive terms and phrases are presented in the following paragraphs for clarity.

A solar event refers to a time, or range of times, that is based on a position of the sun (i.e. a solar position) at a particular location. Examples of solar events, include early morning, sunrise, mid-morning, solar noon, afternoon, sunset, evening, astronomical dawn, astronomical twilight, astronomical dusk, nautical dawn, nautical twilight, nautical dusk, civil dawn, civil twilight, civil dusk, night, and daylight. Other solar events may be defined in some embodiments.

The solar event "early morning" may be defined as a predetermined time period from a time before sunrise up until sunrise. In one embodiment, early morning may be, for example, a twilight period of time in which sunlight reaches the earth but before sunrise at a geographic location. In one embodiment, early morning may be a chosen artificial twilight period of time, such as, for example, a time period for which a user is awake before sunrise, or a predefined time set by the user.

The solar event "sunrise" may be defined as the time at which the upper edge of the sun becomes visible over the eastern horizon in the morning at a geographic location on a particular date. In one embodiment, sunrise may be defined as a range of time on either side of a moment of sunrise.

The solar event "mid-morning" may be defined as a predetermined time period starting after sunrise and lasting until solar noon at a geographic location on a particular date. In one embodiment, mid-morning may begin at a mid-point between the time of sunrise and the time of solar noon.

The solar event "solar noon" may be defined as the time when the sun passes the meridian of a geographic location and reaches its highest position in the sky at that geographic location on a particular date. In one embodiment, solar noon may be defined as a range of time on either side of the moment of solar noon.

The solar event "afternoon" may be defined as a predetermined time period starting after solar noon and lasting until sunset at a geographic location on a particular date. Afternoon may begin at a mid-point between the time of solar noon and the time of sunset.

The solar event "sunset" may be defined as the time at which the trailing edge of the sun stops being visible and disappears below the western horizon in the evening at a geographic location on a particular date. In one embodiment, sunset may be defined as a range of time on either side of a moment of sunset. The time between sunrise and solar noon may or may not be equal to the time between solar noon and sunset, depending on the geographic location and the time of year.

The solar event "evening" may be defined as a predetermined time period from sunset until a time after sunset. In one embodiment, evening may be, for example, a twilight period of time in which sunlight still reaches the earth but after sunset at a geographic location. In one embodiment, evening may be a chosen artificial twilight period of time, such as, for example, a time period for which a user is awake after sunset, or a predefined time set by the user.

In some embodiments, astronomical/nautical definitions of solar times may be used to describe solar events. Astronomical dawn and dusk may be defined as the time when the sun is 18 degrees below the horizon respectively in the morning and evening, nautical dawn and dusk as the time when the sun is 12 degrees below the horizon respectively in the morning and evening, and civil dawn and dusk as the time when the sun is 6 degrees below the horizon respectively in the morning and evening. Astronomical twilight is the time range when the sun is between 12 and 18 degrees below the horizon, nautical twilight is the time range when the sun is between 6 and 12 degrees below the horizon, and civil twilight is the time range when the sun is between 0 and 6 degrees below the horizon. Astronomical, nautical, and civil twilight can each occur both in the morning and the evening. Night may be defined as the time between astronomical dusk and astronomical dawn, between sunset and sunrise, or by some other combination of solar positions, depending on the embodiment. Likewise, daylight may be defined as the time between sunrise and sunset, or some other combination of solar positions, depending on the embodiment.

It will be understood that the predetermined solar events may be defined differently, depending on the embodiment. Additionally, a user may shift the actual time of the solar events to artificial times. For example, a user who may be traveling to a second geographical location in a second time zone may shift the solar events to match the second geographical location in the second time zone, while still residing at the first geographical location in the first time zone, in order to condition their body in preparation for the travel.

Tunable Lighting Systems

Conventionally, lighting systems were either single-color or required complex color-programming at the source of the fixture or in an analog manner. In accordance with the present disclosure, DC tunable lighting control allows for central power control and central command control for changing light output of light fixtures to match lighting scenes based on solar events or other conditions, such as by assigning CCT and/or brightness, which may be used to maintain and/or correct circadian rhythms. Further, the present disclosures reduce the complexity for users to set-up such systems by eliminating analog programming and providing user interfaces that provide automatic and/or simplified programming.

Some luminaires (i.e. light fixtures) may provide two DC power inputs that respectively drive light sources (e.g. LEDs) in the luminaire. Such light fixtures depend on external DC power supplies to drive the two DC power inputs. These external DC power supplies may be integrated into a single unit with multiple DC power outputs, or they may be separate devices each having a single DC power output, depending on the embodiment, although a single system may use some DC power supplies with multiple outputs, and others with a single DC power output. As referred to herein, a DC power supply refers to a portion of a device that has a separately controllable DC power output and may refer to an entire stand-alone device or may refer to a portion of a larger device with multiple functions and/or DC power outputs. Thus, a device having a single DC power output is referred to as a DC power supply, and a device having four separately controllable DC power outputs may be referred to as a first DC power supply, a second DC power supply, a third DC power supply, and a fourth DC power supply. A system according to the present disclosure includes at least one device acting as one or more DC power supplies is connected to a power source, such as an AC power source (e.g. a 120 VAC power output driven from the AC power grid), a battery, a generator, a solar panel, or any other type or combination of types of power sources.

In some embodiments, the DC power supply may provide a set voltage and vary the current based on the number of luminaires (and therefore the number of LEDs) being driven. This may be referred to as a constant voltage (CV) driver. When this approach is used, the luminaires are connected in parallel with each other and the voltage provided by the DC power supply is set based on the specifications of the luminaires. In other embodiments, the DC power supply may provide a set current and vary the voltage based on the number of luminaires (and therefore the number of LEDs) being driven. This may be referred to as a constant current (CC) driver. When this approach is used, the luminaires are connected in series and the current provided by the DC power supply is set based on the specifications of the luminaires. Such luminaires have a power output which can be connected to the next luminaire in the series and a terminator may be used to complete the circuit on the last luminaire in the series.

Brightness of an LED can be controlled by modulating the power delivered by the driver (i.e. the DC power supply) to the LED load. Because LEDs have a non-linear response to voltage, analog modulation of the voltage for dimming is not commonly used with a CV driver. To dim an LED load with a CV driver, the power is commonly modulated using pulse width modulation (PWM) or pulse density modulation (PDM), both of which affect the percentage of a given time period that the voltage is applied to the LED load which digitally modulates the power delivered. The time period is typically chosen to be short enough that most people cannot detect any flickering, such as 16 milliseconds (ms) or less, with the PWM or PDM modulation being performed for each time period. So, for example if a 25% brightness is desired, a PWM system may repeatedly turn the voltage on for 4 ms and then turn off the voltage for 12 ms before turning the voltage back on again and repeating. It should be noted that DC power, as the term is used herein, encompasses a PWM or PDM modulated signal, even if the voltage during the 'off' periods goes negative, as long as substantially all of the power transfer to the LEDs is during the 'on' periods of the PWM/PDM modulation.

While a CC driver can use PWM or PDM to modulate the power delivered to the LED load, a CC driver can dim the LED load by changing the DC current level delivered to the LED load, which is an analog modulation of the power delivered. This technique for dimming an LED has an advantage over PWM and PDM in that it eliminates high frequency flicker from the LEDs that can cause health issues such as migraines. Note that as the current is modulated, the voltage level may vary in a non-linear way due to the characteristics of LEDs.

The DC power supplies, as the phrase is used herein, can use any technique to vary the amount of power delivered at their outputs, including those described above of PWM or PDM with a constant voltage or by regulating (or modulating) the current in an analog manner. The DC power supplies have the ability to communicate with a controller through a communication interface. Any type of communications interface may be used, including, but not limited to, DMX, Ethernet®, Wi-Fi®, universal serial bus (USB), Digital Addressable Lighting Interface (DALI), or optical communications.

The DC power supplies may be installed with their power outputs coupled to power inputs of one or more luminaires by any type of suitable electrical cable or conductor, including, Romex® NM cable, Ethernet cable (e.g. Cat5 or Cat6 cable), individual multi-stranded or solid insulated wires, a jacketed multi-conductor cable, or another type of cabling. The conductors used should have low-enough resistance to minimize the power lost in the cable (and heat generated) and be insulated to avoid short-circuits with other cables or metal structures. Appropriate regulations such as the Uniform Electrical Code should also be followed in the selection of the cable to use to connect the DC power supplies to the luminaires and in the installation of the lighting system.

Going back to the luminaires, in some embodiments, the first power input of the luminaire is used to drive as a first set of one or more LEDs having a first spectral characteristic (i.e. light having particular spectrum of output) having a first correlated color temperature (CCT) and the second power input of the luminaire is used to drive a second set of one or more LEDs having a second spectral characteristic having a second CCT.

The first set of LEDs in a luminaire may all be identical, such as all orange LEDs having a light output in a narrow spectral band at about 600 nanometers (nm) or all warm white LEDs using a phosphor to emit a broad spectrum of light output have a CCT of 2000K, or the first set of LEDs may be a mix of LEDs, such as a mix of red, green, and blue LEDs selected to emit a warm white output having a CCT of 2400K. Any mix of LEDs that when driven by an adequate amount of power through the first power input emits light with a CCT of less than about 4000K (i.e. >250 M) can be used for the first set of LEDs in the luminaires although some embodiments may use a first set of LEDs that emit light at a CCT of about 2400 K or lower (417 M or higher). The LEDs of the first set of LEDs may be referred to herein as "orange LEDs" even if they are actually some other type of LED, such as a red LED, a warm white LED, or a mix of LED types.

The second set of LEDs may all be identical, such as all blue LEDs having a light output in a narrow spectral band at about 480 nm or all cool white LEDs using a phosphor to emit a broad spectrum of light output have a CCT of 6500K, or the second set of LEDs may be a mix of LEDs, such as a mix of red, green, and blue LEDs selected to emit a cool white output having a CCT of 5000K. Any mix of LEDs that when driven by an adequate amount of power through the second power input emits light with a CCT of more than about 4000K (i.e. <250 M) can be used for the second set of LEDs in the luminaires although some embodiments may use a second set of LEDs that emit light at a CCT of about 5000K or higher (i.e. 200 M or lower). The LEDs of the second set of LEDs may be referred to herein as "blue LEDs" even if they are actually some other type of LED, such as a cool white LED or a mix of LED types.

Luminaires with a first set of LEDs emitting light with a first CCT driven by a first DC power input, and a second set of LEDs emitting light with a second CCT driven by a second DC power input may be referred to as tunable luminaires as their light output can be tuned to have a range of brightness and CCT depending on the relative power delivered to their two DC power inputs. Because the light output of an LED is non-linear with power, and different luminaires may use different types of LEDs, information about the characteristics of a particular luminaire may be useful in determining the power to provide to its two DC power inputs in order to achieve a particular target brightness and/or CCT of its light output. Such information may be provided in a profile for a particular luminaire or for a particular type of luminaire which may be identified, as a non-limiting example, by its manufacturer and model number. Profiles for a variety of different luminaires and/or types of luminaires may be predetermined by their manufacturer or by a third party and stored in a database, which may be accessible through the internet or distributed by some other method.

A lighting controller (which may also be referred to as a bridge controller or virtual bridge controller) may be used to control the lighting output of one or more luminaires. The lighting controller may be communicatively coupled to two or more DC power supplies which are then electrically connected to the two DC power inputs of one or more tunable luminaires as described above. The lighting controller may be configured to understand what DC power supplies it can control and what luminaires are coupled to the DC power supplies. This configuration may be automatically performed using standard or proprietary network discovery protocols, done manually by a user, or by a combination of automatic discovery and manual configuration.

The lighting controller may then obtain profiles for the luminaires that it is able to control. The profiles may be obtained automatically during the configuration process through retrieval from a database based on information received about the luminaires, or the profiles may be manually uploaded to the lighting controller by a person (e.g. a technician) configuring the system. The profiles provide information to the lighting controller about how much power should be provided to each DC power input of the luminaire in order to achieve a particular brightness and/or CCT for that luminaire.

At various times, the lighting controller may determine that the brightness and/or CCT for a set of (one or more) luminaires connected to a pair of DC power supplies should be changed. It can use the target brightness and/or target CCT, along with the profile for the luminaires, to determine an amount of power that the two DC power supplies should provide in order to achieve the target brightness and/or target CCT and then it can send commands to the two DC power supplies to set them to deliver the calculated power to the set of luminaires.

The lighting controller may transmit signals to the two DC power supplies indicative of one or more changes in settings to produce changes in the light output from the luminaires at different times throughout the day, which may be referred to as one or more scenes. The lighting controller may transmit signals indicative of commands to the DC power supplies to send power, stop sending power, or change the amount of power sent, to produce one or more scenes that produce multiple changes in the light output from the luminaires at different times throughout the day.

The lighting controller may convert signals indicative of one or more changes in settings of the DC power supplies to DMX before transmitting the signals to the DC power supplies. However, it will be understood that the lighting controller may utilize other communication standards over any type of medium (e.g. wired, radio frequency, optical, and the like) for communications with the DC power supplies. In one embodiment, the lighting controller may transmit signals using UDP (User Datagram Protocol) or TCP (Transmission Control Protocol) to communicate through a wired network such as Ethernet or a wireless network such as Wi-Fi to control the output of the DC power supplies and to send power, stop sending power, or change the amount of power sent, to produce one or more scenes that produce multiple changes in the light output from the DC tunable luminaires at different times throughout the day. Some implementations may utilize Art-Net to transmit DMX information using UDP over Ethernet or some other network.

The change from a first scene, that is, a first CCT value and/or dimness/brightness for the light output of the luminaires, to a second scene, that is, a second CCT value and/or dimness/brightness for the light output of the luminaires, may be implemented as a step change or as a progressive change. A step change is an abrupt change that occurs from one moment to the next. A progressive change is a gradual change that takes place over time. In one embodiment, the gradual change is a series of small step changes between the beginning of the first scene and the beginning of the second scene.

For example, for the change from an "early morning" scene to a "sunrise" scene, the lighting controller may implement a step change from a 40% dim light output at a CCT having a value of 2000K to 100% brightness at 2600K at the minute of the time occurrence of sunrise. Alternatively, the lighting controller may implement a gradual change over a time period, for example 60 seconds, to change the brightness and CCT at a rate of 1% and 10K per second to make the same amount of change at the sunrise solar event. In another embodiment, the change may take place over the entire period between events, so if the early morning event occurs 60 minutes prior to the sunrise event, the lighting controller may change the brightness and CCT at a rate of 1% and 10K per minute to gradually change from 40% brightness at 2000K at the early morning event to 100% brightness at 2600K at sunrise.

The DC power supplies may receive the signal(s) indicative of the power changes and may send the indicated power to the first power input and second power input of the luminaires to produce the one or more scene. The luminaires then react by emitting the light output produced by the first LED(s) driven by the first DC power input and the second LED(s) driven by the second DC power input (either one of which may be turned off for some scenes) at the time(s) of the occurrence of the predetermined solar events and/or at predetermined times assigned for the predetermined solar events.

A lighting controller may use a profile for a tunable luminaire to compile a 24-hour program to control the tunable luminaire to have a human-centric lighting output compatible with human circadian rhythms. This program can be stored in solid state memory on a controller. The controller may be separate from or embedded within the power supply powering the luminaire. Power on/off to the fixture may be controlled by a standard single or multi pole toggle switch. When the circuit is closed, the connected light fixture produces light with the CCT and brightness as dictated by the system based on the time of day. The system can automatically adjust the CCT and brightness throughout the day for the purpose of circadian entrainment. The system may include a graphical user interface (GUI) on a user device which allows for the solar scenes to be customized for CCT and brightness. This customization may be global for an installation or unique to lighting zones within the system. The customized programming may be compiled on the user device and transferred to the controller. The default levels may remain on the controller, allowing the controller to revert back to the default levels without extensive reprogramming. The controller may have more than one set of default levels, such as constant levels that may be used before the controller is initialized, and a default human-centric cycle based on the time of day that is compatible with most people's circadian rhythm.

Existing circadian lighting systems are typically wireless and depend on network communication on both the local and wide area network, both reducing reliability. Existing systems offer little or no options for customization of CCT and brightness. The system disclosed herein can function normally without a network connection. A network connection is only required if a user wants to customize scenes. The automatic, easily customized scenes and the reliability that comes from a network independent system may be factors in human-centric lighting being widely adopted.

The controller may ship with a default 24-hour program to control connected fixtures to produce light for circadian entrainment indefinitely without additional configuration or intervention. If customization is desired, the system can also allow for that. Power level profiles may be created for human centric lights and stored in a central database accessible over the internet. Software (e.g. a mobile device app) can reference these profiles and determine the correct power levels for the connected fixtures to produce light for circadian entrainment for every minute throughout the day. The software can then create a 24-hour program for CCT and brightness for the installed fixtures and transfer the program to a controller. The controller can run the program and send commands to power supplies to send the programmed power levels to connected light fixtures to produce light of a predetermined CCT and brightness for the time of day.

If a user so chooses, a GUI may be provided on a user device which allows for further customization of scenes by changing transition times, color (including CCT), and/or brightness. This customization may be applied to the entire lighting installation or limited to zones within the installation, such as rooms within a home and may be set up to be temporary for a specific period, or permanent until changed again. This is useful if persons with differing sleep time inclinations occupy the same home. Persons traveling to time zones other than the one they typically occupy may desire levels similar to the location to which they are traveling or said person may desire the levels of their original time zone at their destination. Persons required to keep schedules other than the traditional wake/sleep cycles may desire levels to boost attention and productivity during times aligning with their schedule.

One leg of each power connection for the installed fixtures may be connected to a toggle switch. This switch can close or open the circuit, supplying or removing power from the connected fixtures for local on/off control. In addition, some embodiments allow the user to easily revert to the default programming. This may be useful in homes with new occupants, hospitals, and hospitality rooms where occupants change regularly, and/or education settings where needs may change from year to year.

Human-centric lighting (HCL) systems have traditionally used wireless control connections and require a cloud network component to operate. They typically do not allow for any customization and may not even offer basic information about what lighting levels they are producing throughout the day. Existing systems are easy to install since they utilize wireless bulbs, but configuration is difficult and missed commands are common with wireless communication. Wireless communication may not be possible in some installations, excluding many locations that can utilize the benefits of HCL. Thus, the lighting controllers described herein may be put to advantageous use in many environments where existing systems cannot.

Reference now is made in detail to the examples illustrated in the accompanying drawings and discussed below.

FIG. **1**A shows a block diagram of an embodiment of a lighting system **100**A. The lighting system **100**A includes one or more luminaires **130** each comprising a first LED having a first spectral characteristic driven by a first direct-current (DC) power input **131** and a second LED having a second spectral characteristic driven by a second DC power input **132**. Embodiments of the luminaire **130** may have any number of LEDs coupled to each of the two DC power inputs **131**, **132**. The lighting system **100**A also includes a first DC power supply **121**, separate from the one or more luminaires **130**, electrically coupled to the first DC power input **131** of the one or more luminaires **130** to drive the first LEDs of the one or more luminaires **130**, and a second DC power supply **122**, separate from the one or more luminaires **130**, electrically coupled to the second DC power input **132** of the one or more luminaires **130** to drive the second LEDs of the one or more luminaires **130**. The electrical coupling of the DC power supplies **121**, **122** to the DC power inputs **131**, **132** of the one or more luminaires **130** can be done with any type and number of electrical conductors and/or cables.

In some embodiments, the lighting system **100**A may include a second luminaire **140** that has a third set of LEDs having a third spectral characteristic coupled to a first power input **141** of the second luminaire **140** and a fourth set of LEDs having a fourth spectral characteristic coupled to a second power input **142** of the second luminaire **140**. The lighting system **100**A may also include a third DC power supply **123** electrically coupled to the first DC power input **141** of the second luminaire **140** to drive the third LEDs of the second luminaire **140**, and a fourth DC power supply **124** electrically coupled to the second DC power input **142** of the second luminaire **140** to drive the fourth LEDs of the second luminaire **140**.

The lighting system **100**A also includes a lighting controller **110**, communicatively coupled to the first DC power supply **121** and the second DC power supply **122** and in some embodiments to the third DC power supply **123** and fourth DC power supply **124**. The lighting controller **110** is separate from the one or more luminaires **130**, **140** and may be separate from the DC power supplies **121**-**124**. The lighting controller **110** is communicatively coupled to the DC power supplies **121**-**124** by a communication channel **120**. The communication channel **120** can be any appropriate set of unidirectional or bidirectional point-to-point communication links between the lighting controller **110** and the power supplies **121**-**124**, including individual direct links to each power supply **121**-**124** from the lighting controller **110**, a hierarchical tree connection channel such as USB, or a daisy-chained communication link such as DMX. The communication channel may also be a bus or network over a wired or wireless media such as, but not limited to, DALI, Ethernet, Wi-Fi, the internet, a mobile telephony network (e.g. a 3G/4G/5G network), and/or Bluetooth®.

The lighting controller **110** may be a dedicated device, purpose-built to be a lighting controller, which may be referred to as a bridge controller as it provides a bridge from a user to the DC power supplies **121**-**124** used to control the luminaires **130**, **140**. In some embodiments, the lighting controller **110** may utilize a general-purpose computing device, such as a computer or a server, running software to implement the functionality of the lighting controller **110**, which may be referred to as a virtual bridge controller. The lighting controller **110** may be located in the same building as the luminaires **130**, **140** and be directly wired to the DC power supplies **121**-**124**, but in some embodiments the lighting controller **110** may utilize a remote server, such as a cloud server, and communicate with the user **150** and the DC power supplies **121**-**124** over the internet.

The lighting controller **110** includes a processor **111** which can be any type of computing device, including, but not limited to, a 32-bit or 64-bit central processing unit (CPU) from Intel or AMD having one or more X86 architecture cores, an embedded ARM® architecture CPU with one or more cores, an 8-bit 8051 architecture processor core, a 32-bit Coldfire processor core, a RISC-V processor core, or any other processor core using any reduced instruction set computer (RISC) or complex instruction set computer (CISC) instruction set architecture having any instruction bit length. The processor **111** may also be implemented in a field-programmable gate array (FPGA) in some embodiments or using an application-specific integrated circuit (ASIC). The lighting controller includes one or more memory devices **115**, such as a dynamic random-access memory (DRAM) and/or a non-volatile flash memory device, coupled to the processor **111**, which can store instructions **117** for the processor **111** to perform any method disclosed herein. In some embodiments, the one or more memory devices **115** may include a user-removeable memory device, such as a Secure Digital (SD) Card or a USB drive.

The lighting controller **110** also includes a power supply control interface **113** and may optionally include a network interface **112**, each coupled to the processor **111**. In some embodiments, the power supply control interface **113** and the network interface **112** may be one and the same (e.g. an Ethernet interface), but in other embodiments, they may be separate interfaces (e.g. a DMX interface for the power supply control interface **113** and a Wi-Fi interface for the network interface **112**). The power supply control interface **113** provides an interface to the communication link **120** used for communication with the power supplies **121**-**124** while the network interface **112** provides an interface to connections used to communicate with control devices such as the remote control **153** and/or the wall switch **157**, as well as other electronic devices which may be used to configure and/or control the lighting system **100**A. The network interface **112** may also provide the lighting controller **110** with access to the internet. Note that the wall switch **157** might not be a traditional 120 VAC switch but may simply be a device which reports the position of a switch (e.g. open or closed, or a brightness level based on a slider or knob) to the lighting controller through the network interface **112** and may not directly control any current flow to the one or more luminaires **130**, **140**. In some embodiments the network interface **112** may be used to communicate with the database **119**, but other embodiments of the lighting controller **110** may have a dedicated interface for the database **119**, such as serial attached storage interface (SATA) or small-computer serial interface (SCSI). The power supply control interface **113** and the network interface **112** can be interfaces to any appropriate communications link, including, but not limited to, DMX, DALI, Ethernet, and Wi-Fi.

The lighting controller **110** is configured to obtain a target CCT for the one or more luminaires **130**, **140** and obtain a profile for the luminaire **130**. The target CCT may be obtained from a user **150** using a remote control **153**, a pre-defined scene associated with a solar event or a time, or from any other source. Predefined scenes, solar events, and/or times, may be stored in the memory **115**, in the database **119**, in a cloud server accessible over the internet, or in any other location. The profile may be stored in memory **115** or may be obtained from a database **119** based on information about the luminaire, such as a model number. The database may be embedded in the lighting controller **110**, may be local with a direct connection to the lighting controller **110**, or may be remote, such as being hosted by a cloud server or a web server accessible to the lighting controller **110** over the internet. In other embodiments, the profile may be provided by a technician during a configuration of the lighting system **100**A.

The lighting controller **110** is further configured to calculate a first target power for the first DC power input **131** of the luminaire **130** and a second target power for a second DC power input **132** of the luminaire **130** based on the target CCT and the profile. The first target power and the second target power are calculated to drive the luminaire **130** to emit light at the target CCT. The lighting controller **130** is also configured to control the first DC power supply **121** to deliver the first target power to the first DC power input **131** of the luminaire **130** and the second DC power supply **122** to deliver the second target power to the second DC power input **132** of the luminaire **130**. The lighting controller **110** can control the DC power supplies **121**, **122** by sending commands over the communication link **120** to the DC power supplies **121**, **122**.

In embodiments that include the second luminaire **140** driven by the third and fourth DC power supplies **123**, **124**, the lighting controller **110** is configured to obtain a second profile, different than the first profile, for the second luminaire **140** and to calculate a third target power for a first DC power input **141** of the second luminaire **140** and a fourth target power for a second DC power input **142** of the second luminaire **140** based on the target CCT and the second profile. The third target power and the fourth target power are calculated to drive the second luminaire **140** to emit light at the target CCT. Note that because the first luminaire **130** may have different characteristics than the second luminaire **140**, the first and second target power may be different than the third and fourth target power but still allow both the first luminaire **130** and the second luminaire **140** to emit light at the target CCT and brightness. Once the third power target and the fourth power target have been calculated, the lighting controller **110** may be configured to control the third DC power supply **123** to deliver the third target power to the first DC power input **141** of the second luminaire **140** and a fourth DC power supply **124** to deliver the fourth target power to the second DC power input **142** of the second luminaire **140**.

Note that the lighting controller **110** may be able to fully function without the use of the network interface **112** by using default scenes built into the controller **110** and stored in the memory **115**. Thus, embodiments without a network interface **112** are possible. Some embodiments may function in a default mode but still include a network interface **112** to allow a user **150** to optionally customize its scenes.

FIG. **1**B shows a block diagram of an embodiment of an expanded lighting system **100**B. The expanded lighting system **100**B includes the elements of the lighting system **100**A but has additional luminaires added. In addition, the user **150** is shown holding a mobile electronic device **155** instead of a remote control **153**, although the remote control **153** could be used with the expanded lighting system **100**B and the mobile electronic device **155** could be used with the lighting system **100**A. Elements described for lighting system **100**A above are still relevant to the expanded lighting system **100**B and descriptions of some elements may not be repeated here.

The expanded lighting system **100**B includes the lighting controller **110** which includes a power supply control interface **113** configured to communicate with two or more power supplies **121-124**, and a network interface **112**, which may be one and the same as the power supply control interface **113** or may be a different network interface, that may be used for communication with a mobile electronic device **155** to allow the user **150** to configure and/or control the lighting system **100**B. The lighting controller **110** also includes a processor **111** coupled to the power supply control interface **113**, and one or more memory devices **115** coupled to the processor **111** and storing instructions **117** to program the processor **111** to perform one or more of the methods described herein.

In at least one embodiment, the instructions **117** program the processor **111** to perform a method that includes obtaining a target CCT for the one or more luminaires **130**A/B/C, **140**A/B/C. The target CCT may be obtained in any way, depending on the embodiment, including determining a solar position for a location of the one or more luminaires **130**A/B/C, **140**A/B/C and determining the target CCT based on the solar position, determining a clock time for a location of the one or more luminaires and determining the target CCT based on the clock time and the location, or receiving the CCT from a user control provided through a device such as the wireless remote control **153**, mobile electronic device **155** with a graphical user interface, or wall switch **157**. The target CCTs to be used for different time periods identified may have been previously set by the user **150** or by a technician at a time that the lighting system **100**B was configured or may be obtained from a site manager or building manager through another electronic device in communication with the lighting controller **110**. In addition to, or in place of, the target CCT, a user control may include a brightness setting and/or an on/off control.

In some embodiments, scenes may be predefined based on clock times or solar events that set a CCT and/or brightness level, with the scene used to obtain the target CCT. In some embodiments, those scenes may automatically control the luminaires **130**A/B/C, **140** A/B/C to turn on at the specified CCT/brightness and/or turn off for the predefined scene, but in other embodiments, the scenes may set a default CCT and/or brightness for that period based on clock time and/or solar events for the location of the luminaires **130**A/B/C, **140**A/B/C and other factors are used to determine whether or not the luminaires **130**A/B/C, **140**A/B/C are off or are turned on at the specified CCT and/or brightness defined by the scene. So, the light switch **157** may be used to determine whether the first luminaires **130**A/B/C and/or luminaires **140**A/B/C are on or not, but when on, the CCT and/or brightness is controlled by the predefined scene. Scenes may also include setting for whether or not to override the current on/off, CCT, and/or brightness settings for a luminaire or set of luminaires **130**A/B/C, **140**A/B/C.

A first profile associated with a first luminaire **130**A may also be obtained. This may be accomplished by obtaining a type identifier of the first luminaire **130**A, such as, but not limited to, a model number, a serial number, a manufacturer, information received from the first luminaire over a digital communication link, information from an RFID tag, and/or information from a QR code, and retrieving the first profile from a database **119** storing a plurality of profiles based on the model number of the first luminaire **130**A. The type identifier may be received directly from the first luminaire **130**A using a network discovery protocol, received from the user **150** through their mobile electronic device **155**, or obtained by some other mechanism. In some embodiments, the type identifier may be obtained through an RFID tag embedded in the first luminaire **130**A that may be read by the mobile electronic device **155** during configuration or from a QR code from a tag attached to the first luminaire **130**A or included on documentation provided with the first luminaire **130**A that may be captured by a mobile electronic device **155** during configuration.

The profile may provide information about what power needs to be provided to the two DC power inputs **131**, **132** of the first luminaire **130**A to achieve the target CCT (and/or target brightness). The profile may include a set of pairs of power supply values corresponding to different CCT values at full brightness, a table of pairs of power supply values with different rows corresponding to different brightness values and different columns corresponding to different CCT values, coefficients for pre-determined equations that calculate power supply values based on CCT values and/or brightness values (e.g. polynomial equations of degree 2, 3, 4, 5, 6, or 7), symbolic representations of equations that calculate power supply values based on CCT values and/or brightness values, computer code to calculate the power supply values based on CCT values and/or brightness values, or any other representation of how to calculate power supply values for a particular CCT and/or brightness value for a particular luminaire.

In some embodiments, a state of the switch **157**, a command from the remote control **153**, or a command from the mobile electronic device **155** is sent to the lighting controller **110** and used to control whether the luminaire **130**A/B/C is on or off, but the target CCT and/or brightness set by a scene is used to set the target DC power delivered to the luminaire **130**A/B/C so that the luminaire **130**A/B/C emits light at the target CCT and/or brightness when turned on. In some embodiments, an actual physical switch on the connections between the DC power supplies **121**,**122** and the luminaires **130**A/B/C may be used to determine whether the luminaires **130**A/B/C are on with the lighting controller **110** controlling the DC power supplies **121**, **122** to deliver the calculated DC power levels to the luminaires **130**A/B/C when the switch is on. In another embodiment, an AC power switch may control whether AC power is provided to the DC power supplies **121**, **122** with the lighting controller **110** controlling the DC power supplies **121**, **122** to deliver the calculated DC power levels to the luminaires **130**A/B/C when the switch is on.

The method performed by the processor **111** also includes calculating a first target power for the first DC power input **131** of the first luminaire **130**A and a second target power for a second DC power input **132** of the first luminaire **130**A based on the target CCT and the first profile. The first target power and the second target power are calculated to drive the first luminaire **130**A to emit light at the target CCT. In some embodiments the method performed by the processor **111** also includes obtaining a target brightness setting for the one or more luminaires **130**A/B/C and calculating the first target power and the second target power further based on the target brightness setting and the first profile, where the first target power and the second target power are calculated to drive the first luminaire **130**A to emit light at the target brightness with the target CCT. The processor **111** then controls the first DC power supply **121** to deliver the first target power to the first DC power input **131** of the first luminaire **130**A and a second DC power supply **122** to deliver the second target power to the second DC power input **132** of the first luminaire **130**A.

The expanded lighting system **100**B also includes a second luminaire **140**A that is driven by a third DC power supply **123** coupled to its first DC power input **141** and a fourth DC power supply **124** coupled to its second DC power input **142**. The method performed by the processor **111** may also then include obtaining a second profile, different than the first profile, for the second luminaire **140**A. This may be done using a type identifier of the second luminaire **140**A to retrieve the second profile from the database **119** or by using any other method, such as those described above. The method performed by the processor **111** also includes calculating a third target power for a first DC power input **141** of the second luminaire **140**A and a fourth target power for a second DC power input **142** of the second luminaire **140**A based on the target CCT (and/or brightness) and the second profile. The third target power and the fourth target power are calculated to drive the second luminaire **140**A to emit light at the target CCT (and/or brightness). The processor **111** then controls the third DC power supply **123** to deliver the third target power to the first DC power input **141** of the second luminaire **140**A and a fourth DC power supply **124** to deliver the fourth target power to the second DC power input **142** of the second luminaire **140**A.

In the expanded lighting system **100**B there are additional luminaires added to create a first set of luminaires **130**A, **130**B, **130**C driven by the first and second DC power supplies **121**, **122** and a second set of luminaires **140**A, **140**B, **140**C driven by the third and fourth DC power supplies **123**, **124**. In order to provide enough power to each of the luminaires in a set of luminaires, the processor **111** determines that N other luminaires **130**B, **130**C of the one or more luminaires are also associated with the first profile and that a first DC power input and a second DC power input of the N other luminaires **130**B, **130**C are respectively electrically coupled to the first DC power input **131** and the second DC power input **132** of the first luminaire **130**A, The first DC power supply **121** is then controlled by the processor **111** to deliver N+1 times the first target power and the second DC power supply **122** is controlled by the processor **111** to deliver N+1 times the second target power. Note that there are two different ways that two or more luminaires can be coupled to the same set of DC power supplies, serially (as shown for the first set of luminaires **130**A, **130**B, **130**C), and in parallel (as shown for the second set of luminaires **140**A, **140**B, **140**C). So, if the processor **111** determines that the first luminaire **130**A and the N other luminaires **130**C, **130**C are serially coupled to the first DC power supply **121** and to the second DC power supply **122**, the processor **111** sets voltages of the first DC power supply **121** and the second DC power supply **122** based on N. For example if the first set of luminaires are all of the same type and the first luminaire **130**A expects to be driven at 12 VDC for full brightness at each DC power input **131**, **132** (which may be determined based on the first profile), the first and second DC power supplies **121**, **122** may be set for a voltage of 3×12=36 VDC and the power delivered controlled by pulse-width modulation (PWM) or pulse-density modulation (PDM) of the outputs to provide the target CCT and/or target brightness.

But if the processor **111** determines that the second luminaire **140**A and the N other luminaires **140**B, **140**C are coupled in parallel to the third DC power supply **123** and to the fourth DC power supply **124**, the processor **111** may set currents of the third DC power supply **123** and the fourth DC power supply **124** based on N. So, for example, if the second set of luminaires **140**A, **140**B, **140**C are all of the same type and the calculated current based on the second profile and target CCT and/or brightness is 1 A for the first DC power input and 2 A for the second DC power input, the processor **111** may multiply those values by 3 to determine how to set the DC power supplies **123**, **124**.

FIG. **1**C shows a block diagram of an alternative embodiment of a lighting system **100**C. The lighting system includes at least one luminaire **130**, each comprising a first LED having a first spectral characteristic driven by a first direct-current (DC) power input **184** and a second LED having a second spectral characteristic driven by a second DC power input **185**. The system **100**C also includes a first DC power supply **171**A, separate from the at least one luminaire **130**, having a first DC power output **181**, and a second DC power supply **171**B, separate from the at least one luminaire **130**, having a second DC power output **182**. In some embodiments, the first DC power supply **171**A and the second DC power supply **171**B may be integrated into a single multi-output power supply having both the first DC power output **181** and the second DC power output **182**.

A switch may be coupled to the first DC power input **184** and the second DC power input **185** of the at least one luminaire **130**, and to the first DC power output **181** of the first DC power supply **171**A and the second DC power output **182** of the second DC power supply **171**B. The switch has an ON state where power from the from the first DC power output **181** of the first DC power supply **171**A flows through the switch **183** to the first DC power input **184** of the at least one luminaire **130**, and power from the from the second DC power output **182** of the second DC power supply **171**B flows through the switch **183** to the second DC power input **185** of the at least one luminaire **130**. The switch also has an OFF state where no power flows into the at least one luminaire **130** from the first DC power supply **171**A or the second DC power supply **171**B. The switch may have a double-pole configuration with a first pole switching a connection (such as the positive or the negative leg) of the first DC power supply **171**A and the second pole switching a connection (such as the positive or the negative leg) of the second DC power supply **171**B, isolated from each other. In other installations, the switch may have a single-pole configuration switching a connection shared by the first DC power supply and the second DC power supply (i.e. a shared leg).

The system **100**C also includes a lighting controller **160** communicatively coupled to the first DC power supply **171**A and the second DC power supply **171**B through a power supply interface **163** by a communication channel **170** and including a clock **164** to provide a time of day. While the lighting controller **160** is shown as a separate device, it may be integrated into a DC power supply such as the multi-output power supply **171**A/B. The communication channel **170** can be any type of communication channel using any type of protocol including those discussed for the communication channel **120** above. The lighting controller **160** is configured to (a) determine a first setting for the first DC power supply **171**A and a second setting for the second DC power supply **171**B based on the time of day, and (b) send the first setting to the first DC power supply **171**A and the second setting to the second DC power supply **171**B at the time of day independent of the state of the switch **183**. The power supply settings may be based on a target characteristic for the at least one luminaire **130** at the time of day. The target characteristic may be any combination of one or more of a correlated color temperature (CCT), a brightness, a hue, a saturation, a lightness, or other characteristics of light. Specific examples of the target characteristic, include, but are not limited to, a brightness, a CCT, a CCT and brightness, and a hue/saturation/lightness combination. The lighting controller **160** periodically repeats (a) and (b) as the time of day changes.

Different implementations of the lighting controller **160** may use different circuitry such as that shown in FIG. **6**A/B/C but the lighting controller **160** shown in FIG. **1**C includes a CPU **161** coupled to the power supply interface **163**, clock **164**, and one or more memory devices **165**. The clock **164** may have a battery **169** to allow the clock **164** to keep an accurate time of day even if the lighting controller **160** is disconnected from power. The lighting controller **160** may be powered from an alternating-current (AC) power source, a DC power source, a battery, or any other appropriate power source.

The memory **165** includes instructions **166** that if executed by the CPU **161**, cause the lighting controller to perform a method for controlling a light characteristic of a luminaire as described herein. The memory **165** may also include table A **167** of information for the luminaire **130** that can be used to determine lighting characteristics for the luminaire **130** at various times of day. In some embodiments, the table A **167** may provide a target characteristic for the luminaire **130** explicitly or implicitly associated with a time of day that can then be used by the lighting controller **160** to calculate power supply settings to send to the DC power supplies **171**A/B using a profile for the luminaire **130** describing its characteristics or using generic calculations to determine power supply settings based on the target characteristics (e.g. CCT and/or brightness). In other embodiments, the table A **167** may directly store power supply settings for the DC power supplies **171**A/B explicitly or implicitly associated with a times of day. The table A **167** may include explicit times associated with each set of information or the period for updating the power supply settings may be implicitly assumed, such as storing one set of information for each hour of a day (24 sets of information), one set of information for each 15 minutes of a day (96 sets of information), one set for each minute of a day (1440 sets of information), one set of information for each hour of a week (168 sets of information), or any other number of sets of information to be evenly distributed over a predetermined period of time. The table A **167** may be used to calculate power supply settings for one or more sets of two or more DC power supplies, such as the multi-output power supply **171**A/B and may be associated with a room A **180** or other grouping of luminaires **130** in one or more circuits.

In some embodiments, the memory **165** may include a second table B **168** of information for luminaires **140**A/B/C that may be associated with a second room B **190** that can be used to determine lighting characteristics for the luminaires **140**A/B/C at various times of day. The luminaires **140**A/B/C are shown connected in parallel, driven by a first DC power connection **194** and a second DC power connection **195** and are commonly switched by switch **193** which is connected to the first DC power output **191** and the second DC power output **192** of the multi-output DC power supply **173**A/B. Power settings may be sent from the lighting controller **160** through its power supply interface **162** over the connection **170** to the multi-output DC power supply **173**A/B.

In some embodiments, the table B **168** may provide the target characteristic for the luminaires **140**A/B/C explicitly or implicitly associated with a time of day that can then be used by the lighting controller **160** to calculate power supply settings to send to the DC power supplies **173**A/B using a profile for the luminaires **140**A/B/C describing its characteristics or using generic calculations to determine power supply settings based on the target characteristics (e.g. CCT and/or brightness). In other embodiments, the table B **168** may directly store power supply settings for the DC power supplies **173**A/B explicitly or implicitly associated with a times of day. The table B **168** may include explicit times associated with each set of information or the period for updating the power supply settings may be implicitly assumed, such as storing one set of information for each hour of a day (24 sets of information), one set of information for each 15 minutes of a day (96 sets of information), one set for each minute of a day (1440 sets of information), one set of information for each hour of a week (168 sets of information), or any other number of sets of information to be evenly distributed over a predetermined period of time. The times associated with the sets of information stored in table B **168** may be the same as for those stored in table A **167** or may be different, depending on the embodiment. The table **168** may be used to calculate power supply settings for one or more sets of two or more DC power supplies, such as the multi-output power supply **173**A/B and may be associated with a room B **190** or other grouping of luminaires **140**A/B/C in one or more circuits.

Some versions of the lighting controller **160** may include a network interface **162** that may communicate with an external device **155** through a connection **158** which may be wired (e.g. a USB connection) or wireless (e.g. Bluetooth or WiFi). The lighting controller **160** may be configured to receive information useable to determine a first setting for the first DC power supply **171**A and the second setting for the second DC power supply **171**B based on the time of day. The information may be stored in the table A **167** or may be used as a temporary setting for the power supplies **171**A/B.

The external device **155** may be a system controller that includes a processor, a user interface (e.g. a GUI) and a network interface both coupled to the processor, and a memory storing instructions that if executed by the processor, cause the system controller **155** to receive an input through the user interface, use the input to select the target characteristic for the at least one luminaire **130** at the time of day, use the target characteristic to generate the information useable to determine the first setting for the first power supply **171**A and the second setting for the second power supply **171**B, and send the information to the lighting controller **160** through the network interface of the system controller and the network interface **162** of the lighting controller **160**.

The CPU **161** executing the instructions **166** and accessing the table **167** in the memory **165** may be referred to as an embodiment of a settings calculator. The settings calculator may be enabled to receive a table **167** through the network interface **162**, store the table **167** in the memory device **165**, retrieve information from the table **167** based on the time of day, and generate a set of power supply settings based on the information. The power supply control interface **163** can send the set of power supply settings to two or more power supplies **171**A/B which are coupled to the luminaire **130**, independent of an ON/OFF state of the luminaire **130**.

The settings calculator may be enabled to receive a second table **168** through the network interface **162**, store the second table **168** in the memory device **165** in addition to a first table **167** holding the information stored therein, retrieve second information from the second table **168** based on the time of day, and generate a second set of power supply settings based on the second information. The power supply control interface **163** can send the second set of power supply settings to additional power supplies **173**A/B, different than the two or more power supplies **171**A/B, coupled to additional luminaires **140**A/B/C, different than the luminaire **130**, independent of an ON/OFF state of the additional luminaires **140**A/B/C. The second set of power supply settings associated with a particular time of day are based on a target characteristic for the additional luminaires **140**A/B/C that may be different than the target characteristic for the luminaire **130** at the particular time of day.

The lighting controller **160** may be configured in some cases to set the time of day of the clock **164** by communicating over the network interface and the settings calculator of the lighting controller may be configured to use constant default values for the power supply settings until the clock has set the time of day.

FIG. **2**A is a schematic diagram of an embodiment of the first luminaire **130** (also used for **130**A, **130**B, and **130**C) and FIG. **2**B is a schematic diagram of an embodiment of the second luminaire **140** (also used for **140**A, **140**B, and **140**C) of the lighting systems **100**A, **100**B, and **100**C. The embodiments shown are as an example only and other embodiments may include any other number and/or configuration of two sets of LEDs driven from two DC power inputs where the first set of LEDs has a CCT of less than 4000K and the second set of LEDs has a CCT of greater than 4000K. So, in at least some embodiments, a luminaire for use in the lighting system **100**B has no electrical power inputs other than the first DC power input **131**/**141** and the second DC power input **132**/**142**. In other embodiments, a luminaire having more than two DC power inputs, such as a first DC power input for a set of red LEDs, a second DC power input for a set or green LEDs, and a third DC power input for a set of blue LEDs may be used, coupled to three DC power supplies under control of a lighting controller as described herein.

The first luminaire **130** includes a first set of LEDs **211** that has three identical first LEDs **211**A, **211**B, **211**C connected in series between the first DC power input **131** and the first power output **133**. The first LEDs **211**A, **211**B, **211**C may have a narrow band emission of orange light or may utilize a phosphor to emit a warm white light as a wide band emission. The first set of LEDs **211**, when driven from the first DC power input **131**, emit light having a CCT less than 4000K, such as 2700K, 2400K, 2000K or lower.

The first luminaire **130** includes a second set of LEDs **221** that has three identical second LEDs **221**A, **221**B, **221**C connected in series between the second DC power input **132** and the second power output **134**. The second LEDs **221**A, **221**B, **221**C may have a narrow band emission of blue light or may utilize a phosphor to emit a cool white light. The second set of LEDs **221**, when driven from the second DC power input **132**, emit light having a CCT greater than 4000K, such as 5000K, 6000K, or higher. Note that while each set of LEDs is shown with its own separate return path, in some embodiments, a shared return path may be used to reduce the combined number of contacts for the combined first and second power inputs **131**, **132** from four to three.

The first luminaire **130** is designed to be used with other luminaires of the same type in series. So, looking at FIG. **1**B, the first power input of luminaire **130**B is electrically connected to the first power output **133** of the first luminaire **130**A and the second power input of luminaire **130**B is electrically connected to the second power output **134** of the first luminaire **130**A (thereby electrically coupling the first and second power inputs of the luminaire **130**B with the first and second power inputs **131**, **132** of the first luminaire **130**A). Configurations may support any number of luminaires in series depending on the characteristics of the first power supply **121** and the second power supply **122** along with the power requirements of the first luminaire **130**. A terminator may be connected between the two contacts of the first power output and between the two contacts of the second power output of the final luminaire in the series to allow for a return path of the current. A luminaire **130** shown in any of the figures provided herein can be assumed to have the terminator included if one of ordinary skill would deem it to be appropriate (e.g. a single luminaire **130** in a lighting circuit or the last luminaire **130**C in a series-connected group of luminaires **130**.

FIG. **2**B is a schematic diagram of an embodiment of the second luminaire **140**. The second luminaire **140** includes a first set of LEDs **231** that has three different first LEDs **231**A, **231**B, **231**C connected in series between the power and return connections of the first DC power input **141**. The first LEDs **231**A, **231**B, **231**C may individually have a narrow band emission of light or may utilize a phosphor to emit a spectrum of color. The first set of LEDs **231**, when driven from the first DC power input **141**, emit light having a CCT less than 4000K, such as 2700K, 2400K, 2000K or lower.

The second luminaire **140** includes a second set of LEDs **241** that has three different first LEDs **241**A, **241**B, **241**C connected in series between the power and return connections of the second DC power input **142**. The first LEDs **241**A, **241**B, **241**C may individually have a narrow band emission of light or may utilize a phosphor to emit a spectrum of color. The second set of LEDs **241**, when driven from the second DC power input **142**, emit light having a CCT greater than 4000K, such as 5000K, 6000K, or higher. Note that while each set of LEDs is shown with its own separate return path, in some embodiments, a shared return path may be used to reduce the combined number of contacts for the combined first and second power inputs **141**, **142** from four to three.

The second luminaire **140** is designed to be used with other luminaires of the same type in parallel. So, looking at FIG. **1**B, the first power inputs of luminaires **140**A, **140**B, **140**C are electrically connected together and the second power inputs of luminaires **140**A, **140**B, **140**C are electrically connected together. Configurations may support any number of luminaires in parallel depending on the characteristics of the third power supply **123** and the fourth power supply **124** along with the power requirements of the second luminaire **140**.

The DC power supplies **121-124**, **171**A/B, **173**A/B may deliver the power delivered to their connected set of luminaires **130**A/B/C, **140**A/B/C by any appropriate method in response to control by the lighting controller **110**. PWM or PDM are examples of how the power delivered can be controlled to a set of luminaires. Examples of technologies for controlling the power delivered to light emitting diodes which may be used with the luminaires **130**, **140** are described, for instance, in U.S. Pat. No. 8,299,987, "Modulation Method and Apparatus For Dimming and/or Colour Mixing Utilizing LEDs", which issued on Oct. 30, 2013; U.S. Pat. No. 8,525,446, "Configurable LED Driver/Dimmer for Solid State Lighting Applications", which issued on Sep. 3, 2013; and U.S. Pat. No. 9,942,954, "Method and System for Controlling Solid State Lighting Via Dithering", which issued on Apr. 10, 2018; all of which are expressly incorporated by reference in their entirety herein.

FIG. **3**A depicts an embodiment of a graphical user interface (GUI) **300** on a mobile electronics device **155** suitable for use with a lighting systems **100**A, **100**B, **100**C using DC-tunable luminaires. The mobile electronics device **155** may be a smartphone, tablet, mobile computer, or any other type of mobile electronics device. The GUI **300**, or an equivalent GUI, may alternatively or additionally be made available on a non-mobile electronics device, such as a desktop computer or kiosk. The GUI **300** may be used to program or configure the lighting controller **110**/**160** by communicating through its network interface **112**/**162**. The GUI **300** provides a mechanism for a user or installer, such as a technician or electrician, to identify and name the luminaires **130**, **140** in the lighting system **100**A, **100**B, **100**C and/or program scenes for the luminaires **130**, **140**. The GUI **300** includes one or more name fields **311-316** for identifying the luminaires **130**, **140** to be controlled, such as the luminaires in a room, a house, an office building, or other structure, for example. In one embodiment, when a user (such as an electrician, an installer, and/or a homeowner) selects one of the name fields **312**, the user can enter a user-friendly name for the set of luminaires to be controlled together, such as "Family Room." Selecting the name field **312** or entering a name into the name field **312** may cause the lighting controller **110**, **162** to activate the luminaires **140**A/B/C associated with that name field, such as be turning on the third and fourth DC power supplies **123**, **124** to a known safe value, to allow the user to positively identify the luminaires **140**A/B/C being controlled.

The GUI **300** may also include switches **321-326** which can be used to indicate whether the luminaires associated with that name field are tunable, that is that they can have their CCT and/or brightness adjusted. Other embodiments may provide two different switches or a three-position switch to indicate whether just the brightness or both the brightness and CCT can be controlled. In at least one embodiment, activation of the tunable switch **322** brings up another menu **370** to allow the user to identify the type of luminaire associated with that name field **312**. The user may scroll through the menu **370** to find the appropriate type identifier of luminaire and then select it within the menu **370** by tapping on the proper type, thus the type identifier of the luminaire may be received from a user. The type identifier may include a model number, a serial number, or a manufacturer. In other embodiments, selecting the tunable switch **322** may initiate an RFID scan to receive information from an RFID tag associated with the luminaire or initiate a QR code scan using a camera of the mobile electronic device **155**. In some embodiments a type of the luminaire may be received from the first luminaire over a digital communication link. Once the type of luminaire for a particular name field, the type information may be used to obtain a profile for the luminaires associated with that name field.

In one embodiment, the GUI **300** may include an Import control **383** that may be used to cause the lighting controller **110/160** to import a floor plan, names of sets of luminaires to be controlled, and/or the type(s) of luminaires. The GUI **300** may also include a Share control **384** that may be used to cause the lighting controller **110/160** to export information regarding the settings of the lighting controller **110/160**, the luminaires, or other settings. In one embodiment, the Share control **384** may allow a user to export names of luminaires and/or wall switches/dimmers to a label maker or printer to print labels for use in a breaker box and/or the luminaires and/or wall switches/dimmers. The GUI **300** may also include a Test control **385** that may cause the lighting controller **110/160** to automatically verify power and control of the luminaires **130**A/B/C, **140**A/B/C, such as by causing them to turn on and off or blink. Clicking the Back control **382** may cause the mobile electronics device **155** to return to a previous GUI and clicking on the Done control **386** may exit the app generating the GUI **300**. Embodiments of the GUI **300** may also provide mechanisms to identify the number and configuration of luminaires controlled together, such as that there are three luminaires **140**A/B/C connected in parallel that are controlled as "Family Room."

FIG. **3**B depicts an embodiment of a GUI **301** on the mobile electronics device **155** suitable for use with a lighting systems **100**A, **100**B, **100**C using DC-tunable luminaires. The mobile electronics device **155** may be a smartphone, tablet, mobile computer, or any other type of mobile electronics device. The GUI **301**, or an equivalent GUI, may alternatively or additionally be made available on a non-mobile electronics device, such as a desktop computer or kiosk. The GUI **301** may be used to set brightness and/or the CCT for luminaires controlled by the lighting controller **110/160** by communicating through its network interface **112/162**. The GUI **301** includes a name **310** of the group of luminaires **130**A/B/C being controlled and a switch/indicator **320** of whether or not those luminaires have tunable CCT and or variable brightness. Information **390** may be provided about the type and/or number and/or configuration of the luminaires **130**A/B/C. A Current Brightness section **392** may show the current brightness of the group of luminaires **130**A/B/C and a selector **393** may be movable by a user to change the brightness. A Current Color Temperature section **394** may show the current CCT of the group of luminaires **130**A/B/C and a selector **395** may be movable by a user to change the CCT. A Test control **385** may cause the luminaires **130**A/B/C to blink, move through their range of brightness, and/or move through their range of supported CCT values. Clicking the Back control **382** may cause the mobile electronics device **155** to return to a previous GUI and clicking on the Done control **386** may exit the app generating the GUI **301**. Other embodiments may allow different scenes to be configured for this group, such as a starting and/or ending solar event or time of day associated with a particular CCT and/or brightness.

So, in embodiments, the lighting controller **110** may obtain a target brightness setting for a first luminaire **130** and calculate the first target power and the second target power further based on the target brightness setting and the first profile. The first target power and the second target power are calculated to drive the first luminaire **130** to emit light at the target brightness with the target CCT. The lighting controller **110** may receive a user control for the first luminaire from a user input device, such as a mobile electronic device **155** with a graphical user interface **301**, and calculate the first target power and the second target power further based on the user control. The user control may include a brightness setting, an on/off control, or the target CCT.

FIG. **3**C depicts an embodiment of a GUI **302** on the mobile electronics device **155** suitable for use with a lighting systems **100**A, **100**B, **100**C using DC-tunable luminaires. The mobile electronics device **155** may be a smartphone, tablet, mobile computer, or any other type of mobile electronics device. The GUI **302**, or an equivalent GUI, may alternatively or additionally be made available on a non-mobile electronics device, such as a desktop computer or kiosk. The GUI **302** may be used to set a schedule for brightness and/or the CCT for luminaires controlled by the lighting controller **110/160** by communicating through its network interface **112/162**. The GUI **302** includes a name **310** of the group of luminaires being controlled and may include a switch/indicator **320** of whether or not those luminaires have tunable CCT and or variable brightness.

The GUI **302** includes entry locations **360** for a user to provide schedule (or modifying an existing schedule) for adjusting the lighting characteristics for the group of luminaires **310** being controlled. In the example shown, the entries **360** include a column for times of day 351, a column for correlated color temperature (CCT) **352** or mired, and a column for brightness **353**. The user may adjust the target characteristics for the luminaires of the identified group **310** for a particular time of day be entering the target characteristic and associated time in the entries **360**. In the example shown, entries **361** set the Kitchen luminaires to have a CCT of 2700K and a brightness of 50% at midnight and entries **362** set them to have a CCT of 3500K and a brightness of 80% at 5:40 AM. So, the target characteristics for the luminaire may include a brightness greater than zero and a correlated color temperature (CCT). Information **390** may be provided about the type and/or number and/or configuration of the luminaires in the GUI **302** or by another GUI (e.g. GUI **301**) in some embodiments which can be used to determine how to convert the target characteristics into power supply settings. The information provided by the user in the entries **360** may be used to create a table which is sent to the controller **110/160** by an app running on a mobile electronic device **155**. The transition between entries may be determined by the embodiment of the app running on the mobile device **155** and/or the embodiment of the lighting controller **110/160**.

Aspects of various embodiments are described with reference to flowchart illustrations and/or block diagrams of methods, apparatus, systems, and computer program products according to various embodiments disclosed herein. It will be understood that various blocks of the flowchart illustrations and/or block diagrams, and combinations of blocks in the flowchart illustrations and/or block diagrams, can be implemented by computer program instructions or by configuration information for a field-programmable gate array (FPGA). These computer program instructions may be provided to a processor of a general-purpose computer, special purpose computer, or other programmable data processing apparatus to produce a machine, such that the instructions, which execute via the processor of the computer or other programmable data processing apparatus, create means for implementing the functions/acts specified in the flowchart and/or block diagram block or blocks. Similarly, the configuration information for the FPGA may be provided to the FPGA and configure the FPGA to produce a machine which creates means for implementing the functions/acts specified in the flowchart and/or block diagram block or blocks.

These computer program instructions or FPGA configuration information may be stored in a computer readable medium that can direct a computer, other programmable data processing apparatus, FPGA, or other devices to function in a particular manner, such that the data stored in the computer readable medium produce an article of manufacture including instructions which implement the function/act specified in the flowchart and/or block diagram block or blocks. The computer program instructions or FPGA configuration information may also be loaded onto a computer, FPGA, other programmable data processing apparatus, or other devices to cause a series of operational steps to be performed on the computer, FPGA, other programmable apparatus, or other devices to produce a computer implemented process for implementing the functions/acts specified in the flowchart and/or block diagram block or blocks.

The flowchart and/or block diagrams in the figures help to illustrate the architecture, functionality, and operation of possible implementations of systems, methods, and computer program products of various embodiments. In this regard, each block in the flowchart or block diagrams may represent a module, segment, or portion of code comprising one or more executable instructions, or a block of circuitry, for implementing the specified logical function(s). It should also be noted that, in some alternative implementations, the functions noted in the block may occur out of the order noted in the figures. For example, two blocks shown in succession may, in fact, be executed substantially concurrently, or the blocks may sometimes be executed in the reverse order, depending upon the functionality involved. It will also be noted that each block of the block diagrams and/or flowchart illustration, and combinations of blocks in the block diagrams and/or flowchart illustration, can be implemented by special purpose hardware-based systems that perform the specified functions or acts, or combinations of special purpose hardware and computer instructions.

FIG. **4** is a flow chart **400** of an embodiment of a method for controlling **410** a correlated color temperature (CCT) of one or more luminaires. The method includes obtaining **420** a target CCT for the one or more luminaires. Any appropriate mechanism can be used to obtain a target CCT. In at least one embodiment, a solar position or a clock time for a location of the one or more luminaires is determined and the target CCT is determined **421** based on those parameters. Scenes defined for particular solar events, solar periods, or time periods may be pre-defined to provide a target CCT. In other embodiments a user input is received **422** to set a target CCT.

The method continues with obtaining **430** a first profile associated with a first luminaire of the one or more luminaires. The profile may be obtained by an appropriate method, but in some embodiments a type identifier of the first luminaire is obtained, and the first profile retrieved **431**, based on the type identifier of the first luminaire, from a database storing a plurality of profiles. The type identifier may include a model number, a serial number, a manufacturer, information received from the first luminaire over a digital communication link, information from an RFID tag, information from a QR code, and or any other information that can be useful in identifying the luminaire. In some embodiments, the type identifier may be received from a user.

In some embodiments, a target brightness setting may be obtained **441** for the one or more luminaires. The target brightness setting may be obtained along with the CCT from predefined scenes in some embodiments. The target brightness (which may be any brightness value including on or off) may be received as a user control to a user input device such as a wall switch, a wireless remote control, or a mobile electronic device with a graphical user interface.

A first target power for a first DC power input of the first luminaire is calculated **440** and a second target power for a second DC power input of the first luminaire is calculated **450** based on the target CCT and the first profile. The first target power and the second target power are calculated to drive the first luminaire to emit light at the target CCT. In embodiments where brightness is controlled, the first target power and the second target power are calculated **440**, **450** further based on the target brightness setting and the first profile with the first target power and the second target power calculated to drive the first luminaire to emit light at the target brightness with the target CCT. In systems where a user control for the first luminaire is received from a user input device, the first target power and the second target power are calculated **440**, **450** further based on the user control.

Once the target powers have been calculated, a first DC power supply is controlled **460** by the lighting controller to deliver the first target power to the first DC power input of the first luminaire and a second DC power supply is controlled **470** by the lighting controller to deliver the second target power to the second DC power input of the first luminaire. The DC power supplies can be controlled through communication from the lighting controller to the DC power supplies through a communication channel such as DMX, DALI, Ethernet, or across the internet from a server running software to implement the lighting controller. Once the DC power supplies have been set to deliver the target power, the lighting controller may wait **490** for further control such as another solar event, a predetermined time, or a user input.

In systems controlling multiple groups with different types of luminaires in different groups, the method may also include obtaining a second profile, different than the first profile, for a second luminaire of the one or more luminaires, and calculating a third target power for a first direct-current (DC) power input of the second luminaire and a fourth target power for a second DC power input of the second luminaire based on the target CCT and the second profile, the third target power and the fourth target power calculated to drive the second luminaire to emit light at the target CCT. A third DC power supply is controlled to deliver the third target power to the first DC power input of the second luminaire and a fourth DC power supply is controlled to deliver the fourth target power to the second DC power input of the second luminaire.

Embodiments may determine **461** a number and configuration of luminaires in a group. This may be done by determining that N other luminaires of the one or more luminaires are also associated with the first profile and that a first DC power input and a second DC power input of the N other luminaires are respectively electrically coupled to the first DC power input and the second DC power input of the first luminaire. This may be accomplished automatically using network discover protocols, manually with user input or a combination thereof. The first DC power supply is then controlled to deliver N+1 times the first target power and the second DC power supply controlled to deliver N+1 times the second target power. In such systems, the lighting controller may determine that the first luminaire and the N other luminaires are serially coupled to the first DC power supply and to the second DC power supply and set voltages of the first DC power supply and the second DC power supply based on N. The lighting controller may alternatively determine that the first luminaire and the N other luminaires are coupled in parallel to the first DC power supply and to the second DC power supply and set currents of the first DC power supply and the second DC power supply based on N.

FIG. **5** shows an example behavior **500** of an embodiment of a lighting system through a day. The lighting system may be any lighting system using elements described herein, such as lighting system **100**A of FIG. **1**A, lighting system **100**B of FIG. **1**B, or lighting system **100**C of FIG. **1**C. But for simplicity, it is assumed that in the lighting system used for the example shown in FIG. **5**, there is only a single set of luminaires, all of the same type, connected to a single pair of DC power supplies under control of the lighting controller.

In one embodiment a lighting controller may receive and/or obtain a geographical location of a user, luminaire, or another geographical location, and/or a desired time zone. The geographical location and/or the time zone may be provided by the user, obtained from, or provided by an electronic device associated with the user, and/or based on the geographical location of the lighting controller. In other embodiments, the lighting controller may have a default time zone and be preset with a time using a battery-backed-up clock. The lighting controller may also receive or obtain solar event information indicative of times of occurrence of predetermined solar events for one or more day at the geographical location and/or in the time zone. The solar event information may be obtained from internally stored default times or external databases, one example of which is provided by Sunrise-Sunset.org. Another example of a source of solar event information is the Global Monitoring Division of the Earth System Research Laboratory of the National Oceanic & Atmospheric Administration of the U.S. Department of Commerce. In one embodiment, the lighting controller may calculate the times of occurrence of predetermined solar events for one or more day at the geographical location or in the time zone based on astronomical algorithm, which are known to people having ordinary skill in the art. In one example, the solar events may be calculated for a single longitude in the time zone at the equator for a particular date and used for all locations in that time zone for all dates of the year. The example 500 uses solar event information for Oklahoma City, OK on Mar. 25, 2020, but a similar example could be shown for any location and date. Thus, times shown in example 500 are provided for that date and location in central daylight savings time (CDT).

In the example 500, the lighting controller has been configured to change the lighting at five different times during the day, sunrise **510** (7:25 AM), sunrise plus 3 hours 520 (10:25 AM), solar noon **530** (1:36 PM), 5:00 PM **540**, and sunset **550** (7:47 PM). These events are chosen as an example only. Any combination of events may be used in embodiments to change the lighting, including solar events, particular times of day, events detected by sensors, or inputs from a user. Example **500** has five different lighting scenes (or periods), sunrise which starts at 7:25 AM and ends at 10:25 AM, mid-morning which starts at 10:25 AM and ends at 1:36 PM, solar noon which starts at 1:36 PM and ends at 5:00 PM, afternoon, which starts at 5:00 PM and ends at 7:47 PM, and night (not shown) which includes 12:00 AM-7:25 AM and 7:47 PM through the end of the day (12:00 AM, Mar. 26, 2020).

The lighting controller may have been previously programmed with assigned settings indicative of scenes which may vary the CCT and brightness for each lighting period. Embodiments may set a CCT and/or brightness for the lighting based on scenes or simply upon events. The lighting controller may have a default setting which is used when a time period assigned to a scene ends and no new setting has been provided, such as being set to off. In other embodiments, the lighting controller may be configured to change the CCT and/or brightness in response to an event, such as sunrise for that particular date, or an input from a sensor, and to leave the CCT/brightness at that level until a new event is detected. In another embodiment, the predefined scenes may set a CCT/brightness to be used another device such as switch or remote control turns on a luminaire, but the predefined scenes may not be used to actually turn a luminaire on if it has been set to be off by the other device. In the example shown the periods each have a defined CCT and brightness setting, with night being off (0% brightness) with no change to the CCT, sunrise being 100% brightness with a CCT value of 2000K, mid-morning being 60% brightness with a CCT value of 3333K, solar noon being 50% brightness with a CCT value of 5000K, and afternoon being 75% brightness with a CCT value of 4000K.

The lighting controller can then detect the events that have been programmed or use a current clock time to see that the next period has been entered and compute power levels for the two DC power supplies driving the luminaires, based on the target brightness/CCT settings and the profile for the luminaires, to set the brightness and CCT of the light emitted by the luminaires to meet the targets. For example 500, the profile for the luminaire may provide a drive type (voltage for CV drive, current for CC drive) for each of its two DC power inputs (which may be an encoded 8 bit value for each selecting one of 256 standard settings in this example) and then provide a two dimensional matrix of 8 bit values (representing a linear percentage of maximum power with '00000000' being 0% and '11111111' being 100%) for each of the two power supplies with one dimension of the matrix being brightness at 5% steps from 0% to 100% and the other dimension being CCT at 250K steps from 2000K to 5000K.

The profile can provide the information about the luminaire in any way, and at any quantization, depending on the embodiment. In the example given, the profile would be a 21×13×16 bit matrix plus two bytes identifying the drive type for a total of 548 bytes. Other embodiments may provide more or less information by changing the quantization (i.e. step size) of the CCT and/or the brightness to change the size of the matrix and/or change the size of the data value for each power supply setting (i.e. a quantization of the power supply setting). For example, another embodiment may change the brightness step size to 10%, reducing the matrix size to 11×13 and use 4 bits to represent the percentage of power for each power supply, reducing the profile size to 145 bytes. Some embodiments may compress the profile using a lossless compression scheme to reduce the amount of storage needed for each profile. Other embodiments may provide equations, such as by providing coefficients for 7 pairs of 5th-degree polynomials corresponding to 7 different CCT values which take the target brightness as their input and generate a power output for a DC power supply, coefficients for a different predefined set of equations each corresponding to a particular brightness value that takes a CCT value as its input and computes power levels, or a symbolic representation of a pair of equations that directly compute the power values based on the CCT and brightness targets. Other embodiments may provide different representations of how to compute target power levels based on target CCT and/or brightness levels.

So, in example 500, the lighting controller determines that the time of the sunrise has occurred and computes a power setting for the first and second DC power supplies to cause the luminaires to generate 100% brightness at a CCT of 2000K for the sunrise scene. It retrieves the profile and looks up the power settings for those targets and may find that the first DC power supply should be set to 100% and second DC power supply should be set to 0%. At three hours after sunrise, the lighting controller accesses the profile to determine settings for a 60% brightness with a CCT value of 3333K for the mid-morning scene, but the profile of this example only has settings for (60%, 3250K) and (60%, 3500K). In some embodiments, the closest settings may be selected and used, such as the 50% setting for each power supply shown. In other embodiments, the power supply settings may be interpolated between the two surrounding settings. So, for example if the profile value for the first power supply is 50% for (60%, 3250K) and 55% for (60%, 3500K), an interpolated value of 51.7% may be calculated for the first power supply.

For each scene setting the two DC power supplies are calculated, so that for the solar noon scene the first power is set to 0% and the second power supply is set to 62% and for the afternoon scene, the first power supply is set to 12% and the second power supply is set to 82%. For the night scene, the luminaires are set to "Off" so both power supplies are set to 0%. Note that the profile information and power levels provided for example 500 may or may not correspond to any actual luminaire but are used for example purposes only. A profile for a particular luminaire may be provided by the manufacturer of the luminaire or generated by a third party by taking measurements of one or more luminaires to determine the profile.

The lighting controller may then transmit signals to the DC power supplies to regulate electrical power sent to first power inputs and second power inputs of the luminaires in the system to produce light from luminaires at the CCT and/or level of brightness assigned to specific solar events or periods at the times of occurrence of the predetermined solar events based on the solar event information. The transition between CCT and/or brightness levels may occur in a single step or may transition over a period of time, depending on the embodiment. The transition may be managed by the lighting controller calculating changing values over a transition period and gradually changing the settings in the DC power supplies. In other embodiments, the DC power supplies may have the ability to ramp the changes themselves.

FIG. **6**A shows a block diagram of an alternative embodiment of a lighting system **600** using an alternative embodiment of a lighting controller **610**. The controller **610** includes a clock **620** to provide a time of day, which may be a real-time clock **620** with battery backup **621** to keep an accurate time of day even if the lighting controller **610** loses its overall power connection. In some embodiments, the clock **620** may be preset for a particular time zone, but in other embodiments, the system **600** may include a user input device to provide a time zone for the real-time clock **620**. The user input device can be provided by an external device, such as a smartphone in communication with the lighting controller **610**, but in the example shown, the user input device is a physical selector switch **615** with settings for each of the 4 major US time zones, Eastern, Central, Mountain, and Pacific, as well as a Test setting "T" to indicate that the lighting controller should use constant default values for the power supply settings which may be useful during installation and inspection/testing of the system **600**.

The controller **610** also includes a settings calculator **640**A, coupled to the clock **620**, to determine power supply settings **633**A for two or more power supplies **681**, **685** based on the time of day. The power supply settings **633**A are based on target characteristics for a luminaire **690** having a first light emitter powered by a first direct current (DC) power supply **681** of the two or more power supplies and a second light emitter powered by a second DC power supply **685** of the two or more power supplies. The target characteristics for the luminaire **690** may include a brightness greater than zero and a correlated color temperature (CCT). The luminaire **690** may be coupled to a first leg **691** of an output of the first power supply **681** and the first leg **695** of an output of the second power supply **685**. The second legs of the power supplies **681**, **685** may be connected together and coupled to one side of a single-pole, single throw switch **699** which is connected to the luminaire **690** to allow an ON/OFF state of the luminaire **690** to be controlled. In some cases, a positive output leg of each power supply **681**, **685** may be commonly connected to the switch **699** and in other cases, a negative output leg of each power supply **681**, **685** may be commonly connected to the switch **699**. In some embodiments controller **610** includes the first power DC power supply **681** and the second DC power supply **685** in a single integrated device.

The lighting controller **610** also includes a power supply control interface **630** configured to send the power supply settings **633**A to the two or more power supplies **681**, **685** independent of an ON/OFF state of the luminaire **690**. The power supply settings **633**A may be sent over a communication link **638** which may be any applicable type of link but may a serial interface using a protocol compliant with Digital Multiplex (DMX) standards to communicate with the two or more DC power supplies **681**, **685** in some embodiments. The serial interface may use a daisy-chained topology where the power supply control interface **630** of the lighting controller **610** communicates with the interface **683** of the first DC power supply **681** over link **638** and the interface **681** repeats the DMX information on the link **639** to the interface **687** of the second DC power supply **685**. The power supply control interface **630** may be configured to periodically send a current set of power supply settings **633**A to the two or more power supplies **681**, **685** that are redetermined by the settings calculator **640**A as the time of day changes.

The settings calculator **640**A includes circuitry **650**A to access a table **665**A residing in memory **660**A based on the time of day. Information retrieved from the table **665**A can be used to determine the power supply settings **633**A. The circuitry **650**A can be any type of circuitry, including, but not limited to, a microprocessor, an FPGA, an ASIC, or discrete circuitry. In some implementations, the controller **610** includes a socket (e.g. a USB connector or an SD Card slot) for a user-replaceable memory device that can be used as the memory **660**A of the settings controller. The settings calculator **660**A may be configured to use constant default values or a default set of power supply settings for the power supply settings **633**A upon determining that no information to determine the power supply settings **633**A can be retrieved through the socket.

In an embodiment, the settings calculator circuitry **650**A may access the table **665**A to determine the next time to change the power supply settings **633**A and then continue to monitor the clock **620** until that time occurs. It may alternatively set up the clock **620** to indicate to the circuitry **650**A that the time has arrived (e.g. through use of an interrupt). Once the time has arrived, the circuitry **650**A may access the table **665**A to obtain the information to determine the power supply settings **633**A for that time. In some cases, the information may include CCT and brightness information that can be used to calculate the power supply settings **633**A, but in other cases, the information retrieved from the table **665**A may be the power supply settings **633**A themselves. The power supply settings **633**A are then sent from the settings calculator **640**A through the power supply control interface **630** to the one or more power supplies **681**, **685**.

FIG. **6**B shows a block diagram of an embodiment of settings calculator **640**B for use in a lighting controller **610**. The settings calculator **640**B includes a memory device **660**B and circuitry **650**B to retrieve information **666**B, **667**B from the memory device **660**B based on the time of day and use the information **666**B, **667**B in the power supply settings generator **679**B to generate a set of power supply settings **633**B. In some cases, the power supply settings **633**B are directly stored in the memory **660**B so the power supply generator **679**B simply passes the information **666**B, **667**B from the memory **660**B out as the power supply settings **633**B. In other implementations, the lighting characteristics (e.g. CCT and brightness) are retrieved from the memory **660**B as the information **66**B, **667**B and they are then used by the power supply generator **679**B, using a profile of an attached luminaire or default equations, to calculate the power supply settings **633**B. The details of the information **666**B, **667**B and the power supply settings **633**B may vary according to the implementation. In at least one embodiment, the information **666**B and the information **667**B each include an 8-bit DMX address and an 8-bit DMX value which are directly passed to the power supply control interface **630** as the power supply settings **633**B. The power supply control interface **630** can then use the DMX addresses to determine where in the DMX signal to place the associated DMX values. Thus, the memory **660**B may store a table of sets of power supply settings associated with corresponding times of day, and the information **666**B, **667**B used to determine the power supply settings includes the set of power supply settings **633**B associated with the time of day. The memory device **660**B may be user-replaceable in some embodiments.

The settings calculator **640**B includes circuitry **650**B configured to periodically access the memory **660**B so that the time of day associated with the information stored in the memory **660**B is implicitly determined based on the address **659**B. The circuitry **650**B receives time-of-day information **622** from the clock **620** and uses a divide-by-counter **652**B to divide the time-of-day information **622** by a predetermined value to increment an address counter **655**B which generates the address **659**B for the memory **660**B. In one example, the clock information **622** may include a pulse 32768 times per second along with a current time. The memory **660**B stores a table of information associated with corresponding times of day with one entry for each power supply to be controlled for a predetermined period, such as, but not limited to, a minute, 15 minutes, or one hour. So, for example, if the memory stores 1440 sets of information (one per minute of a 24-hour day), the divide-by-counter **652**B, may increment the address counter **655**B once every 47,185, 920 pulses (32768×1440) in the clock information **622** to update the address sent to the memory **660**B. The memory **660**B then retrieves the information **666**B, **667**B and the power supply settings generator **679**B generates the power supply settings **633**B for the current time of day to send to the power supplies. The circuitry **650**B also includes a comparator **653**B to determine when midnight occurs. The address counter **655**B may be reset at midnight to restart the sequence of lighting characteristics.

Thus, the circuitry **679**B of the settings calculator **640**B may be configured to periodically retrieve updated information **666**B, **667**B from the memory device **660**B based on the time of day and generate an updated set of power supply settings **633**B based on the updated information **666**B, **667**B as the time of day changes. The power supply control interface **630** is configured to periodically send the updated set of power supply settings **633**B to the two or more power supplies **681**, **685** independent of the ON/OFF state of the luminaire **690**. In some embodiments, the information **666**B, **667**B is stored in a table that has at least 96 entries, and a period for repeating said retrieving, generating, and sending is no greater than 15 minutes. In some embodiments, the information **666**B, **667**B is stored in a table that has at least 1440 entries, and a period for repeating said retrieving, generating, and sending is no greater than 1 minute.

FIG. **6**C shows a block diagram of an alternative embodiment of a settings calculator **640**C for use in a lighting controller **610**. The settings calculator includes circuitry **650**C, to receive time of day information **622** from the clock **620**, use a divide-by-counter **652**C to increment an address counter **655**C that generates an address **659**C based on a time of day and reset the address counter **655**C based on a comparator **653**C that determines when the time-of-day information **622** indicates midnight. The circuitry **650**C may operate identically to the circuitry **650**B shown in FIG. **6**B.

The settings calculator **640**C also includes an interpolator **670** that receives the information **668**C retrieved from the memory device **660**C storing a table of information associated with corresponding times of day and generates the power supply settings **633**C. While one interpolator **670** is shown, multiple sets of interpolator circuitry may be included to interpolate multiple values retrieved from memory **660**C. First information associated with a time earlier than the time of day that was previously retrieved from memory **660**C is stored in the previous information register **672** and second information associated with a time no earlier than the time of day is retrieved from the table of information in the memory **660**C and stored in the next information register **671**.

An interpolator **670** can then calculate an interpolated set of power supply settings **633**C based on both the first information stored in the previous information register **672** and the second information stored in the next information register **671**. So, the power supply settings **633**C for the two or more power supplies **681**, **685** sent by the power supply control interface **630** include the interpolated set of power supply settings **633**C. The interpolator **670** may operate by calculating a difference between the first information stored in the previous information register **672** and the second information stored in the next information register **671** using a subtraction circuit **673** and dividing the difference by the number of interpolation steps that will be generated at divider **675** to generate the increment value to use for the interpolation. So as one example, the table of information stored in memory **660**C may have 24 or fewer entries for a 24-hour period and the settings calculator **640**C may be configured to recalculate the interpolated set of power supply settings at least every 15 minutes. So, if the table in memory **660**C has 24 entries (one per 60-minute period), the difference generated by the subtraction circuitry **673** is divided by 4 (60 minutes divided by 15 minutes), so the divider **675** simply shifts the difference right by two bits. In another example, the table of information may have 10 or fewer entries and the settings calculator **640**C may be configured to recalculate the interpolated set of power supply settings at least once every minute. So, if the table in memory holds 8 entries (providing a new target value every 3 hours) and power supply settings **633**C are updated 256 times per period (every 1,382,400 ticks of the 32,786 Hz clock or about every 42.2 seconds), the divider **675** can shift the difference 8 bits to the right, keeping all the bits intact for further arithmetic operations. This ensures that the most an interpolated value can vary from one value to the next is about 0.4% of the maximum value.

The interpolator **670** includes a sequencer **645** to control the interpolation process. For the first value sent after a next information register **671** is loaded from memory **660**C and the previous information register **672** is loaded with the data previously held in the next information register **671**, the sequencer **645** controls the mux **674** to select the data from the previous information register **672** and controls AND gates **676** to output a zero so that the adder **677** simply passed the value from the previous information register **672** to the interpolated value register **678**. For each interpolation cycle after that until the number of interpolation steps has been completed, the sequencer **645** controls the mux **674** to select the value from the interpolated value register **678** and the AND gates to pass the increment value from the divider **675** so that the adder **677** adds the increment value to the pervious interpolated value and stores the new interpolated value in the interpolated value register **678**. The output of the interpolated value register **678** is used by the power supply settings generator **679**C to generate the power supply settings **633**C to send to the two or more power supplies **681**, **685**.

Using an interpolator **670** may allow the settings calculator to recalculate the interpolated set of power supply settings periodically and to ensure that any two consecutive interpolated power supply settings have a difference of less than 1% of the maximum value and/or any two consecutive interpolated power supply settings cause an imperceptible difference in a light output of the luminaire powered by the two or more power supplies, which may be, for example, a difference of less than 50K in a correlated color temperature (CCT) of light from the luminaire powered by the two or more power supplies.

FIGS. **7**A and **7**B show power supply output levels for several examples that could be generated from embodiments. FIG. **7**A shows power supply output levels **710** for a first DC power supply A1 and a second DC power supply A2 generated based on power supply settings sent from a lighting controller for a first room A based on a set of lighting parameters associated with various times of day. It also shows power supply output levels **720** for a third DC power supply B1 and a fourth DC power supply B2 generated based on power supply settings sent from a lighting controller for a second room B based on a set of lighting parameters associated with various times of day.

Referring now to the power supply output levels **710**, four sets of lighting parameters are shown, 2000K/100% @ 12 AM, 3333K/60% @ 6 AM, 5000K/50% at 12 PM, 4000K/75% @ 6 PM, and then starting a repeat of the 24-hour period with 2000K/100% @ 12 AM of the next day. Because the settings are evenly distributed at 6-hour intervals, they may be stored in a table with an implicit assumption to their timing. A profile of an attached luminaire may be used to convert the lighting parameters into power supply settings which are then sent to the first set of two or more power supplies, DC power supply A1 and DC power supply A2. Alternatively, instead of storing the lighting parameters, the actual power supply settings for those lighting parameters may be stored. For purposes of this example, 2000K/100% can be generated from the luminaire with a setting for DC power supply A1 of about 10% and a setting for DC power supply A2 of 80%. In this example, the lighting controller interpolates between values, so the next set of lighting parameters (3333K/60% @ 6 AM) are retrieved and power supply settings of 25%/25% are calculated and an interpolation from 10%/80% to 25%/25% is started and the interpolated power supply settings calculated and sent from the lighting controller to the two DC power supplies periodically.

At 6 AM, the 25%/25% power supply settings generated from the 3333K/60% lighting parameters are sent to the two DC power supplies and the next set of lighting parameters (5000K/50%) associated with 12 PM are retrieved and the power supply settings (50%/10%) for those parameters are calculated and an interpolation over the period of 6 AM to 12 PM is started. This is repeated for each set of lighting parameters and repeated for each day (or week or whatever period is used for the repeat cycle).

Through the use of interpolation, any two consecutive updated sets of power supply settings may have a difference of less than 1% of the maximum value. Any two consecutive updated sets of power supply settings may cause an imperceptible difference in a light output of the luminaire powered by the two or more power supplies. Any two consecutive updated sets of power supply settings in the table may cause a difference of less than 50K in a correlated color temperature (CCT) of light from the luminaire powered by the two or more power supplies. By using interpolation, fewer sets of information may need be stored to achieve smooth transitions for the lighting. As a non-limiting example, some embodiments may achieve smooth results using a table that has 24 or fewer entries and a period for recalculating and sending a power supply setting is no greater than 15 minutes. In another embodiment, smooth results may be generated using a table that has 10 or fewer entries and a period no greater than 1 minute.

Referring now to the power supply output levels **720**, five sets of lighting parameters are shown, 3000K/100% @ 12 AM, 4000K/100% @ 4 AM, 5000K/75% at 9 AM, 4000K/75% @ 3 PM, 2000K/100% at 7 PM, and then starting a repeat of the 24-hour period with 3000K/100% @ 12 AM of the next day. Because the settings are not evenly distributed through the day, they may be stored in table with an explicit start time which is retrieved and used to determine when to change the power supply settings. A profile of an attached luminaire may be used to convert the lighting parameters into power supply settings which are then sent to the first set of two or more power supplies, DC power supply B1 and DC power supply B2. Alternatively, instead of storing the lighting parameters, the actual power supply settings for those lighting parameters may be stored. For purposes of this example, 3000K/100% can be generated from the luminaire with a setting for DC power supply B1 of about 50% and a setting for DC power supply B2 of 50%. In this example, the lighting controller does not interpolate between values so those power supply settings remain in place (or are repeatedly sent periodically) until 4 AM when the next set of lighting parameters (4000K/100%) are retrieved and power supply settings of 65%/30% are calculated and sent to the two DC power supplies. This continues for each set of information in the table until the cycle repeats again at midnight. Note that while only 5 periods are shown for the power supply levels **720**, any number of sets of information may be stored either with explicit times or implicitly associated with times based on a predetermined period. So, if enough sets of information are stored, the lighting parameters may be changed smoothly. In some cases, the information is stored in a table that has at least 96 entries, and a period for updating the power supply settings is no greater than 15 minutes.

FIG. **7**B shows power supply output levels **730** for a DC power supply C1 and a DC power supply C2 generated based on power supply settings sent from a lighting controller for a third room C based on information stored in a table in a memory that is associated with various times of day. It also shows power supply output levels **740** for a DC power supply D1 and a DC power supply D2 sent from a lighting controller that has not yet been initialized or is set to send constant default power supply settings.

Referring now to the power supply output levels **730**, a table may have 1440 sets of power supply settings, one for each minute of a day. Every minute, a new set of power supply settings is retrieved from the table and sent to the two DC power supplies C1/C2. This can allow for nearly arbitrary changes in the lighting characteristics of the luminaire during a 24-hour period. So, in at least one embodiment information is stored in a table that has at least 1440 entries, and a period for repeating sending the power supply settings is no greater than 1 minute. As such, any two consecutive power supply settings may have a difference of less than 1% of the maximum value and/or cause an imperceptible difference in a light output of the luminaire powered by the two or more power supplies, such as causing a difference of less than 50K in a correlated color temperature (CCT) of light from the luminaire powered by the two or more power supplies.

Referring now to the power supply output levels **740**, in some embodiments, if the lighting controller has not yet been initialized, or if the lighting controller is set to an installation/test mode, the lighting controller may use a predetermined set of power supply settings the correspond to a fixed lighting configuration for the luminaire. The predetermined set of power supply settings may be sent periodically to the two or more power supplies. Using the predetermined set of power supply settings allows for installation/testing/inspection without any question as to what the brightness or CCT of the luminaires is set for. Once the lighting controller has been initialized and/or set for normal operation, it may start updating the power supply settings for the human-centric lighting.

FIG. **8**A shows a flow chart **800** of aspects of an embodiment of a method for controlling **810** a light characteristic of a luminaire. The method may be implemented in one of the lighting controllers and/or lighting systems described herein, and/or may be implemented by software running on another device in communication with power supplies powering tunable luminaires. The method may check to see if the lighting controller has been initialized **812**. Initialization may be determined by any method, including checking a user input on the lighting controller itself (e.g. the user input device **615** in FIG. **6**A), by checking to see if an initialization flag in the lighting controller has been set (which may have been set by an external device through a network interface, by local software accessing external resources through the network interface, or by other mechanisms), by checking to see if a table in memory has been initialized, by checking to see if a time zone or time-of-day for a clock has been set, or by any other mechanism. If the lighting controller has not yet been initialized, the lighting controller may send **815** default power supply settings to one or more power supplies powering one or more tunable luminaires. The lighting controller can periodically check **812** to see if it has been initialized and continue to periodically send **815** default power supply settings until it has been initialized. So, in at least one embodiment, the lighting controller will use constant default values for the power supply settings until an input to set a local time is received.

Once it has been detected that the lighting controller has been initialized **812**, the lighting controller periodically obtains settings **820** for two or more DC power supplies driving one or more tunable luminaires and sends **890** the power supply settings to the power supplies independent of an ON/OFF state of the luminaire(s). Thus, the power supply settings are sent no matter if a switch between the power supplies and the luminaire(s) is on or off. The periodic obtaining of the power supply settings **820** and sending **890** the power supply settings to the power supplies may continue indefinitely or until explicitly disabled and may repeat at any frequency, depending on the embodiment.

In some embodiments, the lighting controller may obtain settings for multiple different sets of power supplies **880** and independently periodically obtain settings **820** for two or more DC power supplies driving one or more tunable luminaires for each set and independently send **890** the power supply settings to the power supplies independent of an ON/OFF state of the luminaire(s). The different sets of power supplies and attached luminaire(s) may be assigned to different rooms or different lighting circuits in a single room.

The methods shown by flowchart **800** may include periodically obtaining a current set of power supply settings, such as by reading them from a table in memory and sending the current set of power supply settings to the two or more power supplies. The power supply settings may be sent using any type of communication interface and protocol, but some embodiments may use a protocol compliant with Digital Multiplex (DMX) standards to communicate with the two or more power supplies. In some cases, the method of flowchart **800** may include communicating over a network interface to receive information to set the time of day which may signify that the lighting controller has been initialized **812** and constant default values for the power supply settings may be used (i.e. sent **815** to the power supplies) until the time of day has been set.

FIG. **8**B shows a flow chart **820** providing further details of an embodiment of a method to periodically obtain power supply settings **820** in FIG. **8**A. This may constitute a method for controlling a light characteristic of luminaire and may include obtaining power supply settings **821** for two or more power supplies based on a time of day. The power supply settings can be based on target characteristics for a luminaire having a first light emitter powered by a first direct current (DC) power supply of the two or more power supplies and a second light emitter powered by a second DC power supply of the two or more power supplies. Once the power supply settings are obtained, they are then sent to the two or more power supplies independent of an ON/OFF state of the luminaire **890** (from FIG. **8**A). In some implementations the target characteristics for the luminaire include a brightness greater than zero and a correlated color temperature (CCT).

The power supply settings may be obtained **821** by accessing a memory **822** to retrieve information based on the time of day and generating **830** a set of power supply settings based on the information. Thus, the power supply settings may be obtained **891** by calculating them based on information retrieved from memory. Alternatively, the power supply settings may be directly stored in the memory, so they may be obtained **891** by simply retrieving them from the memory. The set of power supply settings are then sent as the power supply setting to the two or more power supplies independent of the ON/OFF state of the luminaire. This may be repeated periodically as the time of day changes. In some embodiments, the memory may be accessed based on both a day identifier (e.g. a date or a day of the week) and the time of day.

In some implementations, the information is stored in a table in memory and a period for repeating the retrieving the information from memory, generating the power supply settings from the information, and sending the power supply settings to the power supplies is constant. In at least one embodiment, the table has at least 96 entries and the period for repeating the retrieving, generating, and sending is no greater than 15 minutes. As an example, the table may include at least 1440 entries, and the period for repeating the retrieving, generating, and sending is no greater than 1 minute. This allows for very small changes in the lighting characteristic to be used and still generate large differences over time to minimize distracting occupants of the room where the luminaires reside. In some cases, any two consecutive sets of power supply settings have a difference of less than 1% of the maximum value and/or, cause an imperceptible difference in a light output of the luminaire. One example of an imperceptible difference is a difference of less than 50K in a correlated color temperature (CCT) of light from the luminaire.

In some embodiments, the memory may store the target parameters for the luminaire, such as the target CCT and brightness, and use information about the luminaire (which may be stored in a profile for the luminaire as described earlier), to calculate the power supply settings to generate that target CCT and brightness. In other embodiments, the memory stores a table of sets of power supply settings associated with corresponding times of day, so the information stored in memory is the set of power supply settings that have been predetermined to cause the luminaire(s) to generate the target CCT and brightness for the time of day associated with that entry in the table.

The table in memory may be set up by any applicable method, including populating it at manufacturing time or by receiving a table of information associated with corresponding times of day through a communication interface and storing the table in the memory. The table of information may be received from an app running on a mobile electronic device, from a server accessed over the internet, or from any other type of electronic device coupled to the communication interface of the lighting controller. In at least one embodiment, the memory may be a removable memory device, such as a Secure Digital (SD) Card, a USB drive, or some other type of removable memory device accessed through a socket (i.e. a connector). The removable memory device may be populated with the table of information by another electronic device and inserted into the lighting controller. In such systems, the lighting controller may detect whether the information is accessible through a socket for a user-removable memory device and send constant default values for the power supply settings in response to detecting that the information is not accessible through the socket, periodically repeating the check to see if the memory device is inserted and contains the table of information. Once the table is accessible through the socket, the information may be accessed from the table and used to generate power supply settings to send to the power supplies.

In some implementations, the lighting controller may be coupled to multiple sets of power supplies driving multiple sets of luminaires. Different lighting parameters for the different sets of luminaires may be supported by storing multiple tables in the memory that can be used to generate different power supply settings for the different sets of power supplies. In such embodiments, the lighting controller may receive a second table through a communication interface and store the second table in the memory. The second table may then be accessed to retrieve second information based on the time of day which is then used to generate a second set of power supply settings which are then sent to additional power supplies, different than the two or more power supplies, coupled to an additional luminaire, different than the luminaire, independent of an ON/OFF state of the additional luminaire. The second set of power supply settings associated with a particular time of day are based on a target characteristic for the additional luminaire that may be different than the target characteristic for the luminaire at the particular time of day.

FIG. **8**C shows a flow chart **830**A of further details of an embodiment of a method to generate power supply settings **830** in FIG. **8**B by using interpolation **831** to minimize the step size of changes in the power supply settings, and therefore in the lighting characteristics of the attached luminaires. The flowchart **830**A continues by determining **832** previous and next information. The previous information may be the information last accessed from a table stored in memory associated with a previous time of day. The time of day may then be updated to an updated time of day, wherein the information becomes previous information associated with a past time of day earlier than the updated time of day. The memory is then accessed again to retrieve next information associated with a future time of day no earlier than the updated time of day. An interpolated set **833** of power supply settings based on both the previous information and the next information is then calculated and sent to the two or more power supplies independent of the ON/OFF state of the luminaire. In some cases, the information is power supply settings, so the interpolated information is the power supply settings; but, in other cases, the interpolated information may be lighting characteristics which are then used to generate **834** the power supply settings based on a profile of the luminaires or other information about how to convert the stored information into power supply settings. This may be repeated periodically as the time of day changes. In some embodiments the table has 24 or fewer entries and a period for repeating is no greater than 15 minutes and in other cases, the table has 10 or fewer entries and a period for repeating is no greater than 1 minute. The interpolation may result in any two consecutive interpolated power supply settings having a difference of less than 1% of the maximum value and/or cause an imperceptible difference in a light output of the luminaire powered by the two or more power supplies, such as a difference of less than 50K in a correlated color temperature (CCT) of light from the luminaire powered by the two or more power supplies.

Refer back to the lighting controller **160** of FIG. **1**C, at least one non-transitory machine-readable medium **165** may include one or more instructions **166** that in response to being executed on a computing device **161** cause the computing device **161** to carry out any of the methods described herein for controlling a light characteristic of a luminaire. So, the controller **160** may include a clock **164** to provide a time of day, a power supply control interface **163** and the at least one non-transitory machine-readable medium **165** storing the one or more instructions **166**. It may also include a processor **161**, communicatively coupled to the clock **164**, the power supply control interface **163**, and the at least one non-transitory machine-readable medium **165**. The processor **161** may the carry one or more of the methods for controlling the light characteristic of the luminaire.

As will be appreciated by those of ordinary skill in the art, aspects of the various embodiments may be embodied as a system, device, method, computer program product apparatus, or article of manufacture. Accordingly, elements of the present disclosure may take the form of an entirely hardware embodiment, an entirely software embodiment (including firmware, resident software, micro-code, or the like) or an embodiment combining software and hardware aspects that may all generally be referred to herein as a "apparatus," "server," "circuitry," "module," "client," "computer," "logic," "FPGA," "system," or other terms. Furthermore, aspects of the various embodiments may take the form of a computer program product embodied in one or more computer-readable medium(s) having computer program code stored thereon. The phrases "computer program code" and "instructions" both explicitly include configuration information for an FPGA or other programmable logic as well as traditional binary computer instructions, and the term "processor" explicitly includes logic in an FPGA or other programmable logic configured by the configuration information in addition to a traditional processing core. Furthermore, "executed" instructions explicitly includes electronic circuitry of an FPGA or other programmable logic performing the functions for which they are configured by configuration information loaded from a storage medium as well as serial or parallel execution of instructions by a traditional processing core.

Any combination of one or more computer-readable storage medium(s) may be utilized. A computer-readable storage medium may be embodied as, for example, an electronic, magnetic, optical, electromagnetic, infrared, or semiconductor system, apparatus, or device, or other like storage devices known to those of ordinary skill in the art, or any suitable combination of computer-readable storage mediums described herein. In the context of this document, a computer-readable storage medium may be any tangible medium that can contain, or store a program and/or data for use by or in connection with an instruction execution system, apparatus, or device. Even if the data in the computer-readable storage medium requires action to maintain the storage of data, such as in a traditional semiconductor-based dynamic random-access memory, the data storage in a computer-readable storage medium can be considered to be non-transitory. A computer data transmission medium, such as a transmission line, a coaxial cable, a radio-frequency carrier, and the like, may also be able to store data, although any data storage in a data transmission medium can be said to be transitory storage. Nonetheless, a computer-readable storage medium, as the term is used herein, does not include a computer data transmission medium.

Computer program code for carrying out operations for aspects of various embodiments may be written in any combination of one or more programming languages, including object-oriented programming languages such as Java, Python, C++, or the like, conventional procedural programming languages, such as the "C" programming language or similar programming languages, or low-level computer languages, such as assembly language or microcode. In addition, the computer program code may be written in VHDL or another hardware description language to generate configuration instructions for an FPGA or other programmable logic. The computer program code if converted into an executable form and loaded onto a computer, FPGA, or other programmable apparatus, produces a computer implemented method. The instructions which execute on the computer, FPGA, or other programmable apparatus may provide the mechanism for implementing some or all of the functions/acts specified in the flowchart and/or block diagram block or blocks. In accordance with various implementations, the computer program code may execute entirely on the user's device, partly on the user's device and partly on a remote device, or entirely on the remote device, such as a cloud-based server. In the latter scenario, the remote device may be connected to the user's device through any type of network, including a local area network (LAN) or a wide area network (WAN), or the connection may be made to an external computer (for example, through the Internet using an Internet Service Provider). The computer program code stored in/on (i.e. embodied therewith) the non-transitory computer-readable medium produces an article of manufacture.

The computer program code, if executed by a processor, causes physical changes in the electronic devices of the processor which change the physical flow of electrons through the devices. This alters the connections between devices which changes the functionality of the circuit. For example, if two transistors in a processor are wired to perform a multiplexing operation under control of the computer program code, if a first computer instruction is executed, electrons from a first source flow through the first transistor to a destination, but if a different computer instruction is executed, electrons from the first source are blocked from reaching the destination, but electrons from a second source are allowed to flow through the second transistor to the destination. So, a processor programmed to perform a task is transformed from what the processor was before being programmed to perform that task, much like a physical plumbing system with different valves can be controlled to change the physical flow of a fluid.

Examples of various embodiments are described in the following paragraphs:

Example 1. A method for controlling a correlated color temperature (CCT) of one or more luminaires, the method comprising: obtaining a target CCT for the one or more luminaires; obtaining a first profile associated with a first luminaire of the one or more luminaires; calculating a first target power for a first direct-current (DC) power input of the first luminaire and a second target power for a second DC power input of the first luminaire based on the target CCT and the first profile, the first target power and the second target power calculated to drive the first luminaire to emit light at the target CCT; and controlling a first DC power supply to deliver the first target power to the first DC power input of the first luminaire and a second DC power supply to deliver the second target power to the second DC power input of the first luminaire.

Example 2. The method of example 1, wherein the first luminaire has no electrical power inputs other than the first DC power input and the second DC power input.

Example 3. The method of example 1 or 2, further comprising: obtaining a type identifier of the first luminaire; and retrieving the first profile from a database storing a plurality of profiles based on the type identifier of the first luminaire.

Example 4. The method of example 3, wherein the type identifier comprises a model number, a serial number, a manufacturer, information received from the first luminaire over a digital communication link, information from an RFID tag, and/or information from a QR code.

Example 5. The method of example 3 or 4, further comprising receiving the type identifier from a user.

Example 6. The method of any of examples 1-5, further comprising: obtaining a second profile, different than the first profile, for a second luminaire of the one or more luminaires; calculating a third target power for a first direct-current (DC) power input of the second luminaire and a fourth target power for a second DC power input of the second luminaire based on the target CCT and the second profile, the third target power and the fourth target power calculated to drive the second luminaire to emit light at the target CCT; and controlling a third DC power supply to deliver the third target power to the first DC power input of the second luminaire and a fourth DC power supply to deliver the fourth target power to the second DC power input of the second luminaire.

Example 7. The method of any of examples 1-6, further comprising: determining that N other luminaires of the one or more luminaires are also associated with the first profile and that a first DC power input and a second DC power input of the N other luminaires are respectively electrically coupled to the first DC power input and the second DC power input of the first luminaire; controlling the first DC power supply to deliver N+1 times the first target power and the second DC power supply to deliver N+1 times the second target power.

Example 8. The method of example 7, further comprising: determining that the first luminaire and the N other luminaires are serially coupled to the first DC power supply and to the second DC power supply; and setting voltages of the first DC power supply and the second DC power supply based on N.

Example 9. The method of example 7, further comprising: determining that the first luminaire and the N other luminaires are coupled in parallel to the first DC power supply and to the second DC power supply; and setting currents of the first DC power supply and the second DC power supply based on N.

Example 10. The method of any of examples 1-10, further comprising: determining a solar position for a location of the one or more luminaires; and determining the target CCT based on the solar position.

Example 11. The method of any of examples 1-11, further comprising: determining a clock time for a location of the one or more luminaires; and determining the target CCT based on the clock time and the location.

Example 12. The method of any of examples 1-11, further comprising: obtaining a target brightness setting for the one or more luminaires; and calculating the first target power and the second target power further based on the target brightness setting and the first profile, the first target power and the second target power calculated to drive the first luminaire to emit light at the target brightness with the target CCT.

Example 13. The method of any of examples 1-12, further comprising: receiving a user control for the first luminaire from a user input device; and calculating the first target power and the second target power further based on the user control.

Example 14. The method of example 13, wherein the user control comprises a brightness setting, an on/off control, or the target CCT; and the user input device comprises a wall switch, a wireless remote control, or a mobile electronic device with a graphical user interface.

Example 15. At least one non-transitory machine-readable medium comprising one or more instructions that in response to being executed on a computing device cause the computing device to carry out a method according to any one of examples 1 to 14.

Example 16. A lighting controller comprising a power supply control interface configured to communicate with two or more power supplies; a processor coupled to the power supply control interface; and one or more memory devices coupled to the processor and storing instructions to program the processor to perform a method according to any one of examples 1 to 14.

Example 17. A direct current tunable lighting control system, comprising: two or more direct current (DC) tunable light fixtures configured to emit light, each of the two or more DC tunable light fixtures comprising: one or more orange LED configured to emit an amount of orange light output, wherein the amount of orange light output correlates with a first amount of power provided to the one or more orange LED, such that an increase in the first amount of power results in an increase in the amount of orange light output and a decrease in the first amount of power results in a decrease in the amount of orange light output; and one or more blue LED, configured to emit an amount of blue light output, wherein the amount of blue light output correlates with a second amount of power provided to the one or more blue LED, such that an increase in the second amount of power results in an increase in the amount of blue light output and a decrease in the second amount of power results in a decrease in the amount of blue light output; one or more direct current (DC) power regulator separate from, but electrically connected to, the two or more DC tunable light fixtures, wherein the DC power regulator is configured to conduct the first amount of power on a first channel to the one or more orange LED of each of the two or more DC tunable light fixtures and to conduct the second amount of power on a second channel to the one or more blue LED of each of the two or more DC tunable light fixtures; and a bridge controller, separate from the two or more DC tunable light fixtures, comprising one or more computer processor configured to execute instructions that cause the one or more computer processor to: receive one or more of a geographical location and a time zone; receive information indicative of times of predetermined solar events for one or more day at the geographical location or in the time zone, wherein the predetermined solar events comprise sunrise, solar noon, and sunset, wherein each of the predetermined solar events has an assigned solar color temperature in a predetermined range; and transmit one or more signal to the DC power regulator at the times of the predetermined solar events, the signal indicative of instructions for the one or more DC power regulator to change at least one of the first amount of power and the second amount of power, such that the light emitted by the two or more DC tunable light fixtures at the times of the predetermined solar events has a fixture color temperature that is in the predetermined range of the assigned solar color temperature of a corresponding predetermined solar event.

Example 18. A direct current tunable lighting control system, comprising: two or more direct current (DC) tunable light fixture configured to emit light, each of the two or more DC tunable light fixtures comprising: one or more orange LED configured to emit an amount of orange light output, wherein the amount of orange light output correlates with a first amount of power provided to the one or more orange LED, such that an increase in the first amount of power results in an increase in the amount of orange light output and a decrease in the first amount of power results in a decrease in the amount of orange light output; and one or more blue LED, configured to emit an amount of blue light output, wherein the amount of blue light output correlates with a second amount of power provided to the one or more blue LED, such that an increase in the second amount of power results in an increase in the amount of blue light output and a decrease in the second amount of power results in a decrease in the amount of blue light output; one or more direct current (DC) power regulator separate from, but electrically connected to, the two or more DC tunable light fixtures, wherein the DC power regulator is configured to conduct the first amount of power on a first channel to the one or more orange LED of each of the two or more DC tunable light fixtures and to conduct the second amount of power on a second channel to the one or more blue LED of each of the two or more DC tunable light fixtures; and a virtual bridge controller, separate from the two or more DC tunable light fixtures, comprising executable instructions, that when executed by one or more computer processor, cause the one or more computer processor to: receive a geographical location or a time zone; receive information indicative of times of predetermined solar events for one or more day at the geographical location or in the time zone, wherein the predetermined solar events comprise sunrise, solar noon, and sunset, wherein each of the predetermined solar events has an assigned solar color temperature in a predetermined range; and transmit one or more signal at the times of the predetermined solar events to the one or more DC power regulator, the signal indicative of instructions to the one or more DC power regulator to change at least one of the first amount of power and the second amount of power, such that the light emitted by the two or more DC tunable light fixtures at the times of the predetermined solar events has a fixture color temperature that is in the predetermined range of the assigned solar color temperature of a corresponding predetermined solar event.

Example 19. A direct current tunable lighting control system, comprising: two or more direct current (DC) tunable light fixture configured to emit light, each comprising: one or more first LED configured to emit an amount of first light output having a first mired value, wherein the amount of first light output correlates with a first amount of power provided to the one or more first LED, such that an increase in the first amount of power results in an increase in the amount of first light output and a decrease in the first amount of power results in a decrease in the amount of first light output; and one or more second LED, configured to emit an amount of second light output, wherein the amount of second light output correlates with a second amount of power provided to the one or more second LED, such that an increase in the second amount of power results in an increase in the amount of second light output and a decrease in the second amount of power results in a decrease in the amount of second light output; one or more direct current (DC) power regulator separate from, but electrically connected to, each of the two or more DC tunable light fixture, wherein the DC power regulator is configured to conduct the first amount of power on a first channel to the one or more first LED and to conduct the second amount of power on a second channel to the one or more second LED; and a bridge controller, separate from the two or more DC tunable light fixtures, comprising one or more computer processor configured to execute instructions that cause the one or more computer processor to: receive a geographical location or a time zone; receive information indicative of times of predetermined solar events for one or more day at the geographical location or in the time zone, wherein the predetermined solar events comprise sunrise, solar noon, and sunset, wherein each of the predetermined solar events has an assigned solar color temperature in a predetermined range; and transmit one or more signal at the times of the predetermined solar events to the DC power regulator, the signal indicative of instructions for the DC power regulator to change at least one of the first amount of power and the second amount of power, such that the light emitted by the two or more DC tunable light fixtures at the times of the predetermined solar events has a fixture color temperature that is in the predetermined range of the assigned solar color temperature of a corresponding predetermined solar event.

Example 20. A method comprising the steps of: receiving, with a bridge controller, information indicative of times of predetermined solar events for one or more day at a geographical location or in a time zone, wherein the predetermined solar events comprise sunrise, solar noon, and sunset, wherein each of the predetermined solar events has an assigned solar color temperature in a predetermined range; and transmitting, at the times of the predetermined solar events with the bridge controller, one or more signal to a DC power regulator connected to two or more direct current (DC) tunable light fixtures, each comprising one or more orange LED and one or more blue LED, one or more signal indicative of instructions to change at least one of a first amount of power transmitted to the one or more orange LED and a second amount of power transmitted to the blue LED, such that light emitted by the two or more DC tunable light fixtures at the times of the predetermined solar events has a fixture color temperature that is in the predetermined range of the assigned solar color temperature of a corresponding predetermined solar event, wherein the bridge controller and the DC power regulator are separate from the two or more DC tunable light fixtures.

Example 21. The example of claim **20**, wherein the bridge controller is a virtual bridge controller.

Example 22. A lighting system comprising: at least one luminaire each comprising a first LED having a first spectral characteristic driven by a first direct-current (DC) power input and a second LED having a second spectral characteristic driven by a second DC power input; a first DC power supply, separate from the at least one luminaire, having a first DC power output; a second DC power supply, separate from the at least one luminaire, having a second DC power output; a switch, coupled to the first DC power input and the second DC power input of the at least one luminaire, the first DC power output of the first DC power supply, and the second DC power output of the second DC power supply, the switch having: an ON state where power from the from the first DC power output of the first DC power supply flows through the switch to the first DC power input of the at least one luminaire, and power from the from the second DC power output of the second DC power supply flows through the switch to the second DC power input of the at least one luminaire; and an OFF state where no power flows into the at least one luminaire from the first DC power supply or the second DC power supply; and a lighting controller communicatively coupled to the first DC power supply and the second DC power supply and including a clock to provide a time of day, the lighting controller configured to: (a) determine a first setting for the first DC power supply and a second setting for the second DC power supply based on the time of day and a target characteristic for the at least one luminaire at the time of day; (b) send the first setting to the first DC power supply and the second setting to the second DC power supply at the time of day independent of the

ON/OFF state of the switch; and periodically repeat (a) and (b) as the time of day changes.

Example 23. The lighting system of example 22, wherein the first DC power supply and the lighting controller are integrated into a single unit.

Example 24. The lighting system of example 22, wherein the first DC power supply and the second DC power supply are integrated into a single multi-output power supply.

Example 25. The lighting system of example 22, the switch comprising a double-pole configuration with a first pole switching a connection of the first DC power supply and a second pole switching a connection of the second DC power supply.

Example 26. The lighting system of example 22, the switch comprising a single-pole configuration with switching a connection shared by the first DC power supply and the second DC power supply.

Example 27. The lighting system of example 22, further comprising: a network interface in the lighting controller, the lighting controller further configured to receive information useable to determine the first setting for the first DC power supply and the second setting for the second DC power supply based on the time of day; and a system controller, the system controller comprising a processor, a user interface and a network interface both coupled to the processor, and a memory storing instructions that if executed by the processor, cause the system controller to: receive an input through the user interface; use the input to select the target characteristic for the at least one luminaire at the time of day; use the target characteristic to generate the information useable to determine the first setting for the first DC power supply and the second setting for the second DC power supply; and send the information to the lighting controller through the network interface of the system controller and the network interface of the lighting controller.

Example 28. A controller comprising: a clock to provide a time of day; a settings calculator, coupled to the clock, to determine power supply settings for two or more power supplies based on the time of day, wherein the power supply settings are based on a target characteristic for a luminaire having a first light emitter powered by a first direct current (DC) power supply of the two or more power supplies and a second light emitter powered by a second DC power supply of the two or more power supplies; a power supply control interface configured to send the power supply settings to the two or more power supplies independent of an ON/OFF state of the luminaire.

Example 29. The controller of example 28, wherein the target characteristic for the luminaire includes a brightness greater than zero and a correlated color temperature (CCT).

Example 30. The controller of example 28, the clock comprising a real-time clock with battery backup.

Example 31. The controller of example 30, further comprising a user input device to provide a time zone for the real-time clock.

Example 32. The controller of example 31, the user input device including an input for the settings calculator to use constant default values for the power supply settings.

Example 33. The controller of example 28, the settings calculator comprising: a memory device; and circuitry to retrieve information from the memory device based on the time of day and generate a set of power supply settings based on the information; wherein the power supply settings for the two or more power supplies sent by the power supply control interface include the set of power supply settings.

Example 34. The controller of example 33, wherein the memory device is user replaceable.

Example 35. The controller of example 33, wherein the memory device stores a table of sets of power supply settings associated with corresponding times of day, and the information comprises the set of power supply settings associated with the time of day.

Example 36. The controller of example 33, wherein the memory device stores a table of information associated with corresponding times of day, and the table has at least one entry for each minute in a day.

Example 37. The controller of example 33, wherein the circuitry of the settings calculator is configured to periodically retrieve updated information from the memory device based on the time of day and generate an updated set of power supply settings based on the updated information as the time of day changes; and the power supply control interface is configured to periodically send the updated set of power supply settings to the two or more power supplies independent of the ON/OFF state of the luminaire

Example 38. The controller of example 37, wherein the information is stored in a table that has at least 96 entries, and a period for repeating said retrieving, generating, and sending is no greater than 15 minutes.

Example 39. The controller of example 37, wherein the information is stored in a table that has at least 1440 entries, and a period for repeating said retrieving, generating, and sending is no greater than 1 minute.

Example 40. The controller of example 37, wherein any two consecutive updated sets of power supply settings have a difference of less than 1% of a maximum value of a power supply setting.

Example 41. The controller of example 37, wherein any two consecutive updated sets of power supply settings cause an imperceptible difference in a light output of the luminaire powered by the two or more power supplies.

Example 42. The controller of example 37, wherein any two consecutive updated sets of power supply settings in the table cause a difference of less than 50K in a correlated color temperature (CCT) of light from the luminaire powered by the two or more power supplies.

Example 43. The controller of example 33, further comprising a network interface; the settings calculator further configured to receive a second table through the network interface, store the second table in the memory device in addition to a first table holding the information stored therein, retrieve second information from the second table based on the time of day, and generate a second set of power supply settings based on the second information; the power supply control interface further configured to send the second set of power supply settings to additional power supplies, different than the two or more power supplies, coupled to an additional luminaire, different than the luminaire, independent of an ON/OFF state of the additional luminaire; wherein the second set of power supply settings associated with a particular time of day are based on a target characteristic for the additional luminaire that is different than the target characteristic for the luminaire at the particular time of day.

Example 44. The controller of example 28, the settings calculator comprising: a memory device storing a table of information associated with corresponding times of day; circuitry to retrieve first information associated with a time earlier than the time of day and second information associated with a time no earlier than the time of day from the table of information; an interpolator to calculate an interpolated set of power supply settings based on both the first information and the second information; wherein the power supply settings for the two or more power supplies sent by the power supply control interface include the interpolated set of power supply settings.

Example 45. The controller of example 44, the table of information having 24 or fewer entries and the settings calculator configured to recalculate the interpolated set of power supply settings at least every 15 minutes.

Example 46. The controller of example 44, the table of information having 10 or fewer entries and the settings calculator configured to recalculate the interpolated set of power supply settings at least every minute.

Example 47. The controller of example 44, the settings calculator configured to recalculate the interpolated set of power supply settings periodically, wherein any two consecutive interpolated power supply settings have a difference of less than 1% of a maximum value of a power supply setting.

Example 48. The controller of example 44, the settings calculator configured to recalculate the interpolated set of power supply settings periodically, wherein any two consecutive interpolated power supply settings cause an imperceptible difference in a light output of the luminaire powered by the two or more power supplies.

Example 49. The controller of example 44, the settings calculator configured to recalculate the interpolated set of power supply settings periodically, wherein any two consecutive interpolated power supply settings cause a difference of less than 50K in a correlated color temperature (CCT) of light from the luminaire powered by the two or more power supplies.

Example 50. The controller of example 28, the power supply control interface configured to periodically send a current set of power supply settings, the current set of power supply settings redetermined by the settings calculator as the time of day changes.

Example 51. The controller of example 50, the power supply control interface configured to use a protocol compliant with Digital Multiplex (DMX) standards to communicate with the two or more power supplies.

Example 52. The controller of example 28, further comprising the first power DC power supply and the second DC power supply.

Example 53. The controller of example 28, further comprising a network interface: the clock configured to set the time of day by communicating over the network interface.

Example 54. The controller of example 53, the settings calculator configured to use constant default values for the power supply settings until the clock has set the time of day.

Example 55. The controller of example 28, further comprising a memory device and a network interface; the settings calculator configured to: receive a table through the network interface; store the table in the memory device; and retrieve information from the table stored in the memory device based on the time of day; and generate a set of power supply settings based on the information; wherein the power supply settings for the two or more power supplies sent by the power supply control interface include the set of power supply settings.

Example 56. The controller of example 55, wherein the table is sent to the controller by an app running on a mobile electronic device.

Example 57. The controller of example 28, further comprising a socket for a user-replaceable memory device; the settings calculator configured to use constant default values for the power supply settings upon determining that no information to determine the power supply settings can be retrieved through the socket.

Example 58. A method for controlling a light characteristic of a luminaire, the method comprising: obtaining power supply settings for two or more power supplies based on a time of day, wherein the power supply settings are based on a target characteristic for a luminaire having a first light emitter powered by a first direct current (DC) power supply of the two or more power supplies and a second light emitter powered by a second DC power supply of the two or more power supplies; sending the power supply settings to the two or more power supplies independent of an ON/OFF state of the luminaire.

Example 59. The method of example 58, wherein the target characteristic for the luminaire includes a brightness greater than zero and a correlated color temperature (CCT).

Example 60. The method of example 58, further comprising using constant default values for the power supply settings until an input to set a local time is received.

Example 61. The method of example 58, further comprising: (a) accessing a memory to retrieve information based on the time of day; (b) generating a set of power supply settings based on the information, wherein the power supply settings include the set of power supply settings; and (c) sending the set of power supply settings to the two or more power supplies independent of the ON/OFF state of the luminaire.

Example 62. The method of example 61, further comprising periodically repeating (a), (b), and (c) as the time of day changes.

Example 63. The method of example 62, wherein the memory is accessed based on both a day identifier and the time of day.

Example 64. The method of example 62, wherein the information is stored in a table that has at least 96 entries, and a period for repeating (a), (b), and (c) is constant and no greater than 15 minutes.

Example 65. The method of example 62, wherein the information is stored in a table that has at least 1440 entries, and a period for repeating (a), (b), and (c) is no greater than 1 minute.

Example 66. The method of example 62, wherein the memory stores a table of sets of power supply settings associated with corresponding times of day, and the information comprises the set of power supply settings associated with the time of day.

Example 67. The method of example 62, further comprising: receiving a table of information associated with corresponding times of day through a communication interface; and storing the table in the memory.

Example 68. The method of example 67, wherein the table of information is received from an app running on a mobile electronic device.

Example 69. The method of example 62, further comprising: detecting whether the information is accessible through a socket for a user-removable memory device; sending constant default values for the power supply settings in response to detecting that the information is not accessible through the socket; and periodically repeating (a), (b), and (c) in response to detecting that the information is accessible through the socket.

Example 70. The method of example 62, wherein any two consecutive sets of power supply settings have a difference of less than 1% of a maximum value of a power supply setting.

Example 71. The method of example 62, wherein any two consecutive sets of power supply settings in the table cause an imperceptible difference in a light output of the luminaire.

Example 72. The method of example 62, wherein any two consecutive sets of power supply settings in the table cause a difference of less than 50K in a correlated color temperature (CCT) of light from the luminaire.

Example 73. The method of example 62, wherein the information is stored in a first table, the method further comprising: receiving a second table through a communication interface; storing the second table in the memory; accessing the second table to retrieve second information based on the time of day; generating a second set of power supply settings based on the second information; and sending the second set of power supply settings to additional power supplies, different than the two or more power supplies, coupled to an additional luminaire, different than the luminaire, independent of an ON/OFF state of the additional luminaire; wherein the second set of power supply settings associated with a particular time of day are based on a target characteristic for the additional luminaire that is different than the target characteristic for the luminaire at the particular time of day.

Example 74. The method of example 58, further comprising: accessing a table stored in a memory to retrieve next information associated with the time of day (a) updating the time of day to an updated time of day, wherein the next information becomes previous information associated with a past time of day earlier than the updated time of day; (b) accessing the memory to retrieve next information associated with a future time of day no earlier than the updated time of day; (c) calculating an interpolated set of power supply settings based on both the previous information and the next information, wherein the power supply settings include the interpolated set of power supply settings; (d) sending the interpolated set of power supply settings to the two or more power supplies independent of the ON/OFF state of the luminaire; and periodically repeating (a) through (d).

Example 75. The method of example 74, wherein the table has 24 or fewer entries and a period for repeating (a) through (d) is no greater than 15 minutes.

Example 76. The method of example 74, wherein the table has 10 or fewer entries and a period for repeating (a) through (d) is no greater than 1 minute.

Example 77. The method of example 74, wherein any two consecutive interpolated power supply settings have a difference of less than 1% of a maximum value of a power supply setting.

Example 78. The method of example 74, wherein any two consecutive interpolated power supply settings cause an imperceptible difference in a light output of the luminaire powered by the two or more power supplies.

Example 79. The method of example 74, wherein any two consecutive interpolated power supply settings cause a difference of less than 50K in a correlated color temperature (CCT) of light from the luminaire powered by the two or more power supplies.

Example 80. The method of example 58, further comprising periodically obtaining a current set of power supply settings and sending the current set of power supply settings to the two or more power supplies, wherein the power supply settings include the current set of power supply settings.

Example 81. The method of example 80, further comprising using a protocol compliant with Digital Multiplex (DMX) standards to communicate with the two or more power supplies.

Example 82. The method of example 58, further comprising communicating over a network interface to receive information to set the time of day.

Example 83. The method of example 82, using constant default values for the power supply settings until the time of day has been set.

Example 84. At least one non-transitory machine-readable medium comprising one or more instructions that in response to being executed on a computing device cause the computing device to carry out a method for controlling a light characteristic of a luminaire, the method being any of the methods of examples 58 through example 62.

Example 85. A controller comprising: a clock to provide a time of day; a power supply control interface; the at least one non-transitory machine-readable medium of example 84; a processor, communicatively coupled to the clock, the power supply control interface, and the at least one non-transitory machine-readable medium, wherein the processor comprises the computing device to carry out the method for controlling the light characteristic of the luminaire.

Unless otherwise indicated, all numbers expressing quantities, properties, measurements, and so forth, used in the specification and claims are to be understood as being modified in all instances by the term "about." The recitation of numerical ranges by endpoints includes all numbers subsumed within that range, including the endpoints (e.g. 1 to 5 includes 1, 2.78, 7C, 3.33, 4, and 5).

As used in this specification and the appended claims, the singular forms "a", "an", and "the" include plural referents unless the content clearly dictates otherwise. Furthermore, as used in this specification and the appended claims, the term "or" is generally employed in its sense including "and/or" unless the content clearly dictates otherwise. As used herein, the term "coupled" includes direct and indirect connections. Moreover, where first and second devices are coupled, intervening devices including active devices may be located there between. Furthermore, "based on" is intended to mean "based, at least in part, on" unless explicitly stated otherwise.

The use of ordinal number terminology (i.e., "first", "second", "third", "fourth", etc.) is solely for the purpose of differentiating between two or more items and, unless explicitly stated otherwise, is not meant to imply any sequence or order or importance to one item over another or any order of addition. As used herein, any reference to "one embodiment" or "an embodiment" means that a particular element, feature, structure, or characteristic described in connection with the embodiment is included in at least one embodiment. The appearances of the phrase "in one embodiment" in various places in the specification are not necessarily all referring to the same embodiment.

The description of the various embodiments provided above is illustrative in nature and is not intended to limit this disclosure, its application, or uses. Thus, different variations beyond those described herein are intended to be within the scope of embodiments. Such variations are not to be regarded as a departure from the intended scope of this disclosure. As such, the breadth and scope of the present disclosure should not be limited by the above-described exemplary embodiments but should be defined only in accordance with the following claims and equivalents thereof

What is claimed is:

1. A method for controlling a correlated color temperature (CCT) of one or more luminaires, the method comprising:

obtaining a target CCT and a type identifier for a first luminaire of the one or more luminaires, wherein the first luminaire includes a first light source that emits light at a first CCT and a second light source that emits light at a second CCT;

selecting a first profile associated with the first luminaire from two or more profiles based on the type identifier of the first luminaire;

calculating a first target power for a first direct-current (DC) power input of the first luminaire to power the first light source of the first luminaire and a second target power for a second DC power input of the first luminaire to power the second light source of the first luminaire based on the target CCT and the first profile, the first target power and the second target power calculated to drive the first luminaire to emit light at the target CCT; and

controlling a first DC power supply to deliver the first target power to the first DC power input of the first luminaire and a second DC power supply to deliver the second target power to the second DC power input of the first luminaire.

2. The method of claim 1, wherein the type identifier comprises a model number, a serial number, a manufacturer, information received from the first luminaire over a digital communication link, information from an RFID tag, information from a QR code and/or information received from a user.

3. The method of claim 1, further comprising:

obtaining a second type identifier for a second luminaire of the one or more luminaires, wherein the second luminaire includes a first light source and a second light source that emit light at different CCTs;

selecting a second profile associated with the second luminaire from two or more profiles based on the second type identifier of the second luminaire;

calculating a third target power for a first direct-current (DC) power input of the second luminaire and a fourth target power for a second DC power input of the second luminaire based on the target CCT and the second profile, the third target power and the fourth target power calculated to drive the second luminaire to emit light at the target CCT; and

controlling a third DC power supply to deliver the third target power to the first DC power input of the second luminaire and a fourth DC power supply to deliver the fourth target power to the second DC power input of the second luminaire.

4. The method of claim 1, further comprising accessing a database storing the two or more profiles to select the first profile.

5. The method of claim 1, further comprising:

obtaining a target brightness setting for the one or more luminaires; and

calculating the first target power and the second target power further based on the target brightness setting and the first profile, the first target power and the second target power calculated to drive the first luminaire to emit light at a brightness corresponding to the target brightness setting and with the target CCT.

6. At least one non-transitory machine readable medium comprising one or more instructions that in response to being executed on a computing device cause the computing device to carry out a method for controlling a correlated color temperature (CCT) of one or more luminaires, the method comprising:

obtaining a target CCT and a type identifier for a first luminaire of the one or more luminaires, wherein the first luminaire includes a first light source that emits light at a first CCT and a second light source that emits light at a second CCT;

selecting a first profile associated with the first luminaire from two or more profiles based on the type identifier of the first luminaire;

calculating a first target power for a first direct-current (DC) power input of the first luminaire to power the first light source of the first luminaire and a second target power for a second DC power input of the first luminaire to power the second light source of the first luminaire based on the target CCT and the first profile, the first target power and the second target power calculated to drive the first luminaire to emit light at the target CCT; and

controlling a first DC power supply to deliver the first target power to the first DC power input of the first luminaire and a second DC power supply to deliver the second target power to the second DC power input of the first luminaire.

7. The at least one non-transitory machine readable medium as claimed in claim 6, the method further comprising:

obtaining a second type identifier for a second luminaire of the one or more luminaires, wherein the second luminaire includes a first light source and a second light source that emit light at different CCTs;

selecting a second profile associated with the second luminaire from two or more profiles based on the second type identifier of the second luminaire;

calculating a third target power for a first direct-current (DC) power input of the second luminaire and a fourth target power for a second DC power input of the second luminaire based on the target CCT and the second profile, the third target power and the fourth target power calculated to drive the second luminaire to emit light at the target CCT; and

controlling a third DC power supply to deliver the third target power to the first DC power input of the second luminaire and a fourth DC power supply to deliver the fourth target power to the second DC power input of the second luminaire.

8. The at least one non-transitory machine readable medium as claimed in claim 6, the method further comprising accessing a database storing the two or more profiles to select the first profile.

9. The at least one non-transitory machine readable medium as claimed in claim 6, the method further comprising:

determining that N other luminaires of the one or more luminaires are also associated with the first profile and that a first DC power input and a second DC power input of the N other luminaires are respectively electrically coupled to the first DC power input and the second DC power input of the first luminaire; and

controlling the first DC power supply to deliver N+1 times the first target power and the second DC power supply to deliver N+1 times the second target power;

wherein N is a positive integer.

10. The at least one non-transitory machine readable medium as claimed in claim **6**, the method further comprising:

determining a location and a clock time for the one or more luminaires;

determining a solar position for the one or more luminaires based on the location and the clock time; and

determining the target CCT based on the solar position.

11. The at least one non-transitory machine readable medium as claimed in claim **6**, the method further comprising:

obtaining a target brightness setting for the one or more luminaires; and

calculating the first target power and the second target power further based on the target brightness setting and the first profile, the first target power and the second target power calculated to drive the first luminaire to emit light at a brightness corresponding to the target brightness setting and with the target CCT.

12. A lighting controller comprising:

a power supply control interface configured to communicate with two or more power supplies for one or more luminaires, the two or more power supplies including a first direct-current (DC) power supply and a second DC power supply;

a processor coupled to the power supply control interface; and

one or more memory devices coupled to the processor, and storing instructions to program the processor to perform a method comprising:

obtaining a target CCT and a type identifier for a first luminaire of the one or more luminaires, wherein the first luminaire includes a first light source that emits light at a first CCT and a second light source that emits light at a second CCT;

selecting a first profile associated with the first luminaire from two or more profiles based on the type identifier of the first luminaire;

calculating a first target power for a first DC power input of the first luminaire to power the first light source of the first luminaire and a second target power for a second DC power input of the first luminaire to power the second light source of the first luminaire based on the target CCT and the first profile, the first target power and the second target power calculated to drive the first luminaire to emit light at the target CCT; and

controlling the first DC power supply to deliver the first target power to the first DC power input of the first luminaire and the second DC power supply to deliver the second target power to the second DC power input of the first luminaire.

13. The lighting controller of claim **12**, further comprising:

the first DC power supply; and

the second DC power supply.

14. The lighting controller of claim **12**, the method further comprising:

obtaining a second type identifier for a second luminaire of the one or more luminaires, wherein the second luminaire includes a first light source and a second light source that emit light at different CCTs;

selecting a second profile associated with the second luminaire from two or more profiles based on the second type identifier of the second luminaire;

calculating a third target power for a first direct-current (DC) power input of the second luminaire and a fourth target power for a second DC power input of the second luminaire based on the target CCT and the second profile, the third target power and the fourth target power calculated to drive the second luminaire to emit light at the target CCT; and

controlling a third DC power supply to deliver the third target power to the first DC power input of the second luminaire and a fourth DC power supply to deliver the fourth target power to the second DC power input of the second luminaire, wherein the two or more power supplies include the third DC power supply and the fourth DC power supply.

15. The lighting controller of claim **12**, the method further comprising accessing a database storing the two or more profiles to select the first profile.

16. The lighting controller of claim **15**, further comprising the database stored in the one or more memory devices.

17. The lighting controller of claim **15**, further comprising a network interface coupled to the processor, wherein the database is accessed through the network interface.

18. The lighting controller of claim **17**, wherein the network interface comprises the power supply control interface.

19. The lighting controller of claim **12**, the method further comprising:

determining a location and a clock time for the one or more luminaires;

determining a solar position for the one or more luminaires based on the location and the clock time; and

determining the target CCT based on the solar position.

20. The lighting controller of claim **12**, the method further comprising:

obtaining a target brightness setting for the one or more luminaires; and

calculating the first target power and the second target power further based on the target brightness setting and the first profile, the first target power and the second target power calculated to drive the first luminaire to emit light at a brightness corresponding to the target brightness setting and with the target CCT.

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