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**Janik et al.**

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(54) **LIGHT TURN-OFF FADE TIME CONTROL**

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*H05B 45/325* (2020.01)

(52) **U.S. Cl.**
CPC .................................. *H05B 45/325* (2020.01)

(58) **Field of Classification Search**
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(Continued)

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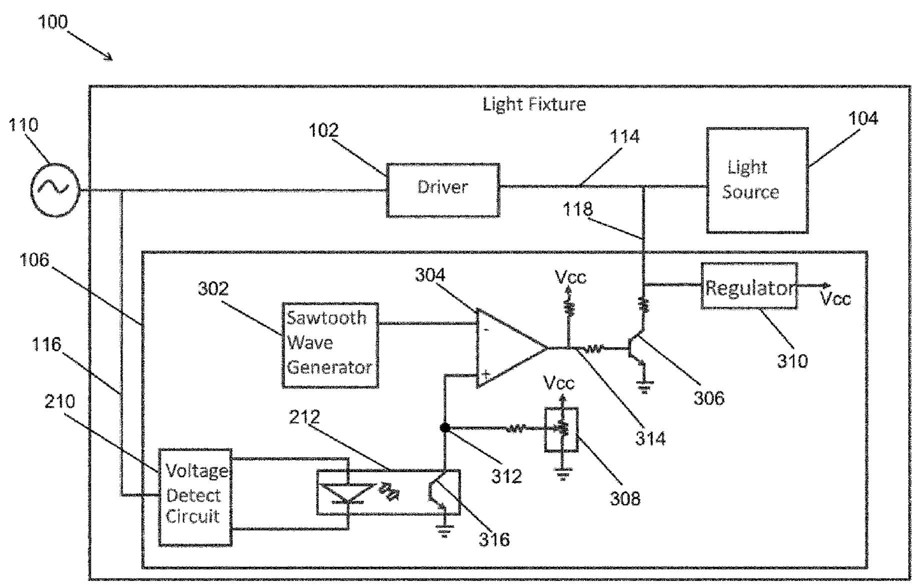
*Primary Examiner* — Ryan Jager

(57) **ABSTRACT**

A light fade controller includes an input power detection circuit configured to detect whether an input power is available. The light fade controller further includes a power discharge circuit configured to enable a power discharge path to discharge output power from a driver circuit through the power discharge path in response to the input power detection circuit detecting that the input power is unavailable. The power discharge circuit is also configured to adjust a rate of power discharge through the power discharge path, and the power discharge circuit either: a) includes a switch (**306**) that is controlled by a pulse width modulation (PWM) control signal to enable and disable the power discharge path and to adjust the rate of power discharge through the power discharge path, wherein a pulse width of the PWM signal is adjusted to enable and disable the power discharge path and to adjust the rate of power discharge through the power discharge path; or b) is configured to adjust the rate of power discharge based on a user input provided to the power discharge circuit.

**9 Claims, 4 Drawing Sheets**



(58) **Field of Classification Search**
USPC .......................................................... 315/291
See application file for complete search history.

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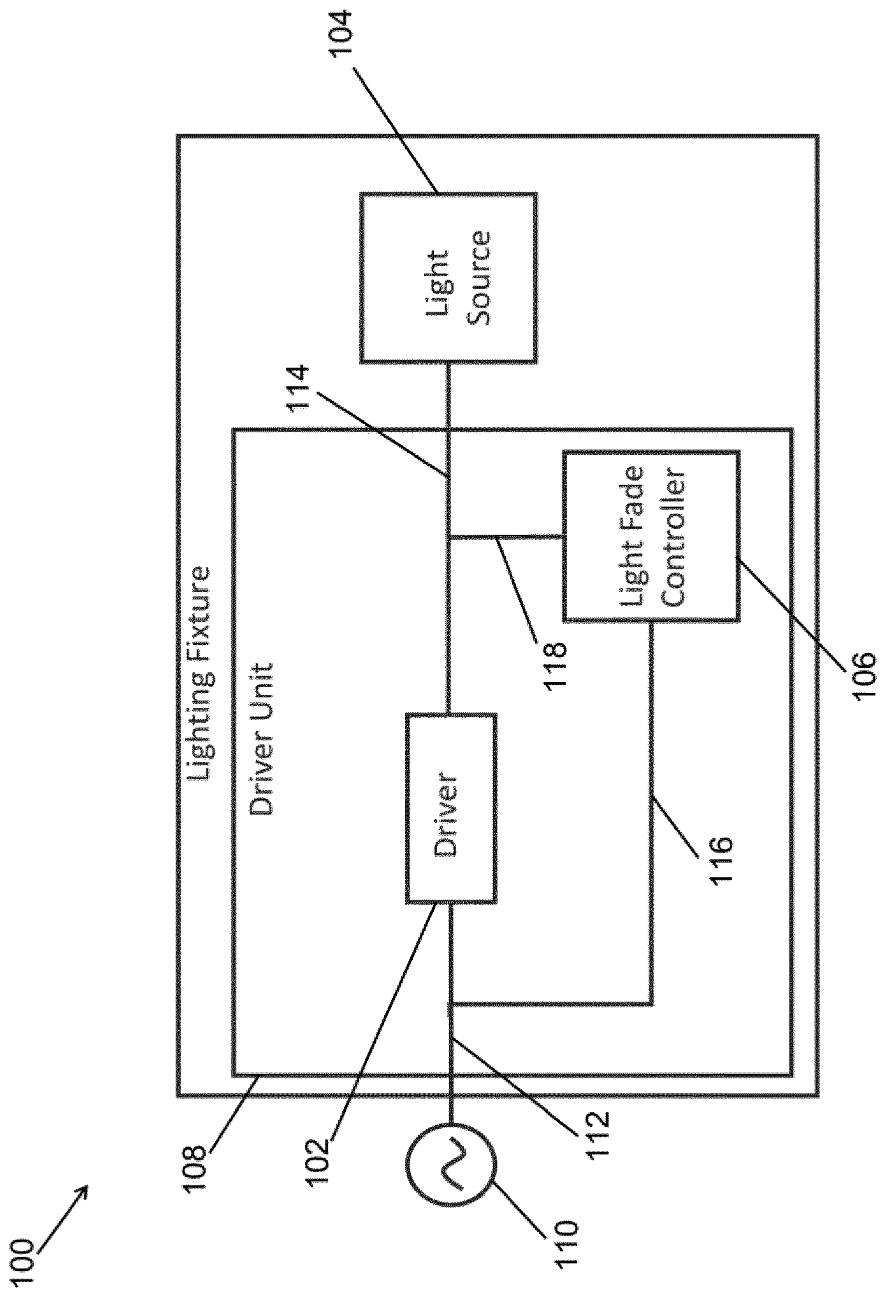
Lighting Fixture
Driver Unit
Light Source
Light Fade Controller
Driver
100
102
104
106
108
110
112
114
116
118

FIG. 1

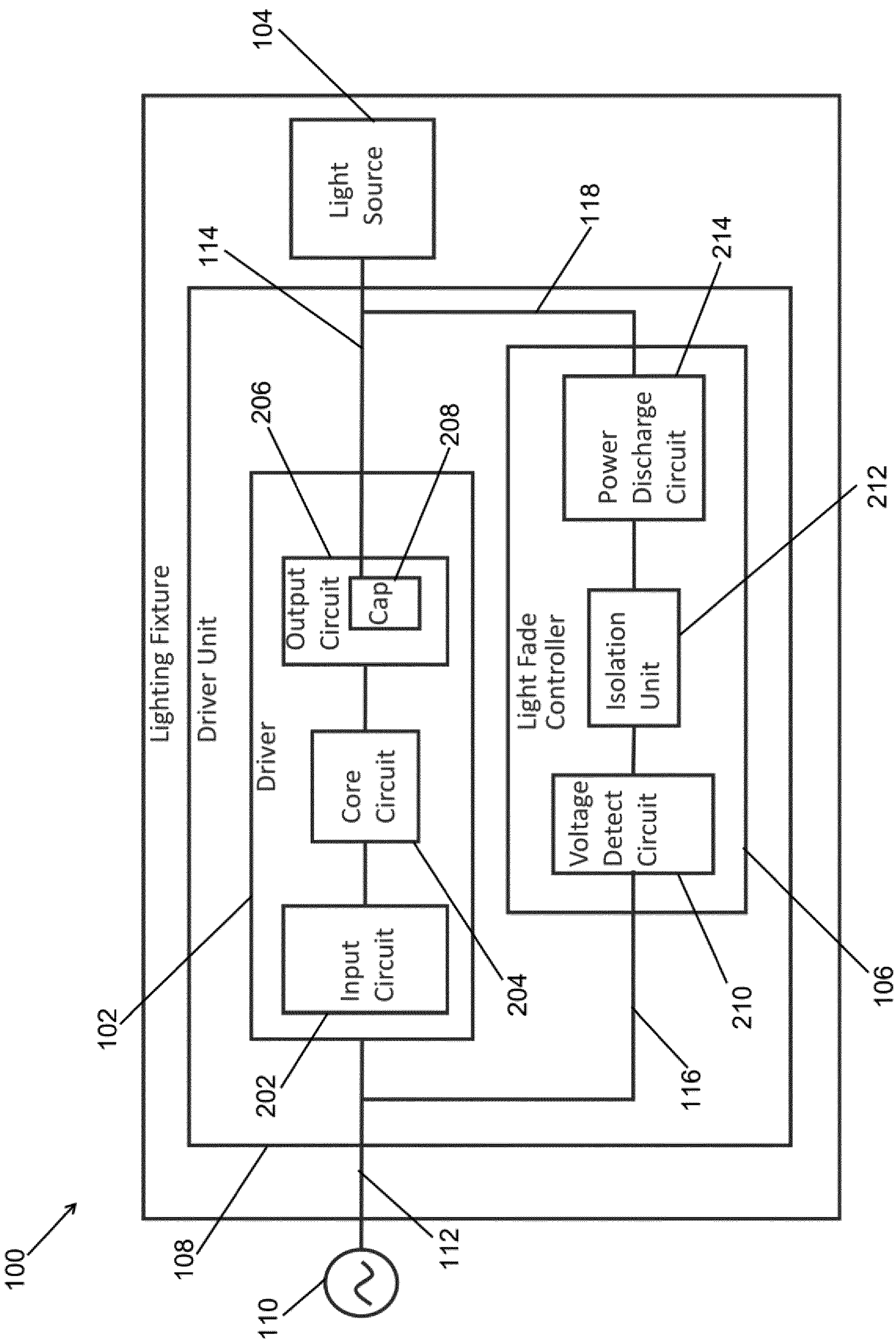
100
Lighting Fixture
Driver Unit
Driver
Light Source
Output Circuit
Cap
Core Circuit
Input Circuit
Light Fade Controller
Power Discharge Circuit
Isolation Unit
Voltage Detect Circuit
102
104
106
108
110
112
114
116
118
202
204
206
208
210
212
214

FIG. 2

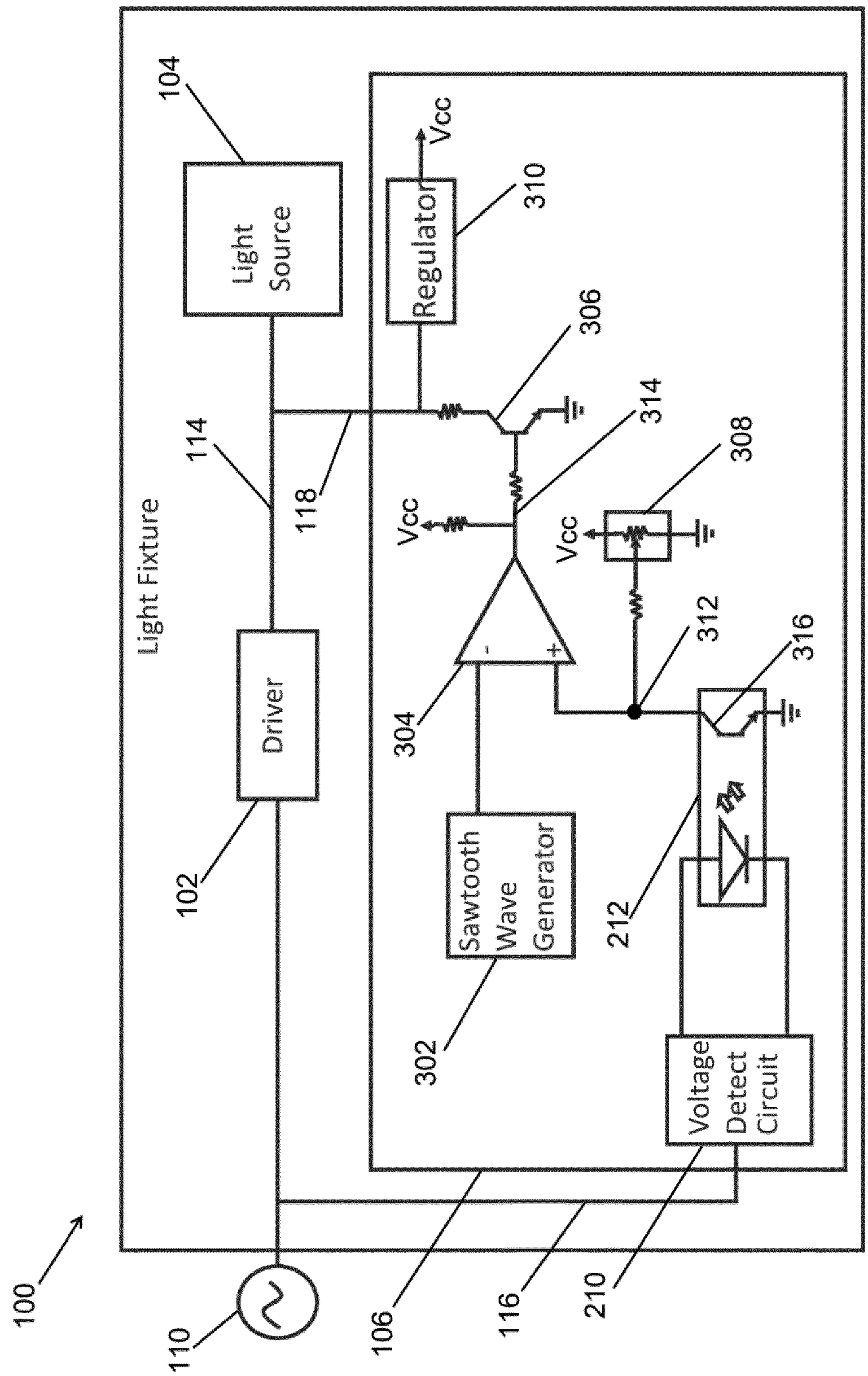
100
104
Light Source
Regulator
Vcc
310
306
314
308
Vcc
Vcc
114
118
Light Fixture
Driver
102
304
312
316
Sawtooth Wave Generator
212
302
Voltage Detect Circuit
110
106
116
210

FIG. 3

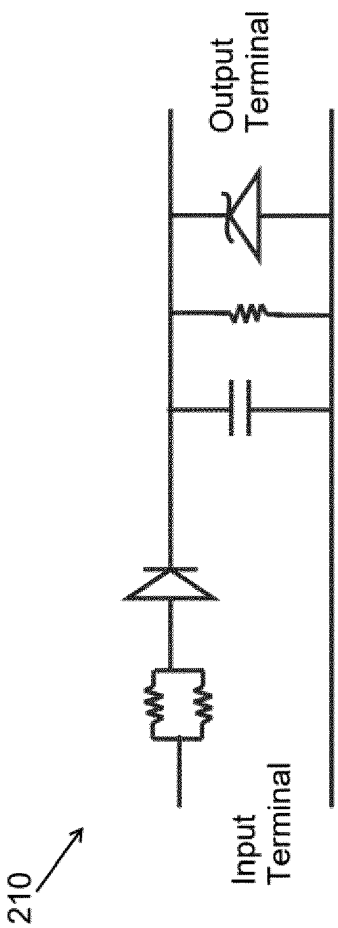


FIG. 4

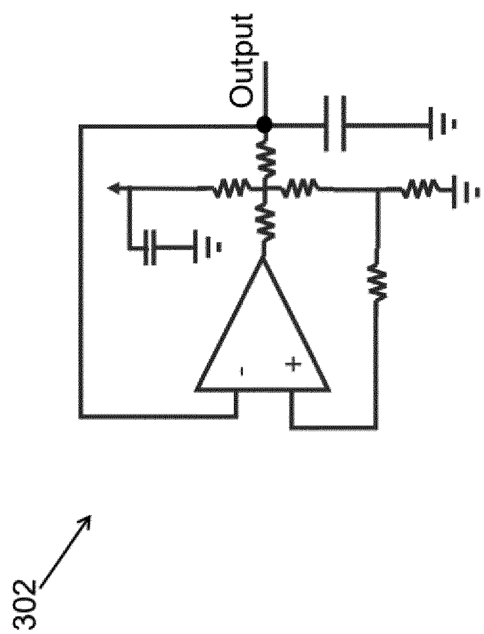


FIG. 5

# LIGHT TURN-OFF FADE TIME CONTROL

## CROSS-REFERENCE TO PRIOR APPLICATIONS

This application is the U.S. National Phase application under 35 U.S.C. § 371 of International Application No. PCT/EP2022/057896, filed on Mar. 25, 2022, which claims the benefit of European Patent Application No. 21168142.4, filed on Apr. 13, 2021, and U.S. Provisional Application Ser. No. 63/167,162, filed Mar. 29, 2021. These applications are hereby incorporated by reference herein.

## TECHNICAL FIELD

The present disclosure relates generally to lighting fixtures, and more particularly to fade times of lights provided by light fixtures.

## BACKGROUND

Drivers are typically used to provide power to light sources and other components of light fixtures. For example, a driver may receive alternating-current (AC) input and provide a direct-current (DC) output to a light source of a light fixture. To illustrate, a current-source LED driver can be used to provide power to a light emitting diode (LED) light fixture. Such drivers typically incorporate one or more DC/output capacitors at the output stages of the driver to reduce flicker in the light provided by light fixtures. For example, an output capacitor that has a relatively larger capacitance generally results in lower light flicker. When the AC power provided to the driver of a light fixture is turned off, a relatively larger capacitance of the output capacitor can result in an increased fade time of the light provided by the light fixture. In a lighting system that has multiple light fixtures that are controlled by a common control (e.g., a switch), tolerance and other differences in relatively large capacitance values of output capacitors of the respective drivers may result in light fade time variations among the lights provided by the light fixtures. In such circumstances, lights from some light fixtures may be completely off while lights from other light fixtures will remain on until respective capacitors are adequately discharged. Thus, a solution that enables adjustments of the fade time of a light provided by a light fixture may be desirable.

## SUMMARY

The present disclosure relates generally to lighting fixtures, and more particularly to fade times of lights provided by light fixtures. In an example embodiment, a light fade controller includes an input power detection circuit configured to detect whether input power is available. The light fade controller further includes a power discharge circuit configured to enable a power discharge path to discharge output capacitor of a driver circuit through the power discharge path in response to the input power detection circuit detecting that the input power is unavailable. The power discharge circuit is also configured to adjust a rate of power discharge through the power discharge path.

In another example embodiment, a driver unit includes a driver circuit configured to receive input power and generate, from the input power, output power compatible with a light source of a lighting device. The driver unit further includes a light fade controller that includes an input power detection circuit configured to detect whether the input power is available to the driver circuit. The light fade controller further includes a power discharge circuit configured to enable a power discharge path to discharge output power from the driver circuit through the power discharge path in response to the input power detection circuit detecting that the input power is unavailable to the driver circuit and to adjust a rate of power discharge through the power discharge path.

These and other aspects, objects, features, and embodiments will be apparent from the following description and the appended claims.



## BRIEF DESCRIPTION OF THE FIGURES

Reference will now be made to the accompanying drawings, where:

FIG. **1** illustrates a light fixture including a light fade controller according to an example embodiment;

FIG. **2** illustrates the light fixture of FIG. **1** including some components of the light fade controller according to an example embodiment;

FIG. **3** illustrates the light fixture **100** of FIGS. **1** and **2** and components of the light fade controller **106** of the light fixture **100** according to an example embodiment;

FIG. **4** illustrates an input power detection circuit of the light fade controller of FIGS. **1** and **2** according to an example embodiment; and

FIG. **5** illustrates a sawtooth wave generator of the light fade controller of FIGS. **1** and **2** according to an example embodiment.

The drawings illustrate only example embodiments and are therefore not to be considered limiting in scope. The elements and features shown in the drawings are not necessarily to scale, emphasis instead being placed upon clearly illustrating the principles of the example embodiments. Additionally, certain dimensions or placements may be exaggerated to help visually convey such principles. In the drawings, the same reference numerals that are used in different drawings designate like or corresponding, but not necessarily identical elements.

## DETAILED DESCRIPTION OF EXAMPLE EMBODIMENTS

In the following paragraphs, particular embodiments will be described in further detail by way of example with reference to the figures. In the description, well known components, methods, and/or processing techniques are omitted or briefly described. Furthermore, reference to various feature(s) of the embodiments is not to suggest that all embodiments must include the referenced feature(s).

FIG. **1** illustrates a light fixture **100** including a light fade controller **106** according to an example embodiment. In some example embodiments, the light fixture **100** includes a lighting driver **102**, a light source **104**, and the light fade controller **106**. For example, the lighting driver **102** may be a standalone driver or a driver circuit that is included in a driver unit **108** along with the light fade controller **106**. The driver **102** may receive input power (e.g., AC power) from a power source **110** via an electrical connection **112** (e.g., one or more electrical wires) and generate output power (e.g., DC power) that is provided to the light source **104**. For example, the driver **102** may be a current source driver, and the output power from the driver **102** may be provided to the light source **104** via an electrical connection **114** (e.g., one or more electrical wires).

In some example embodiments, the light source **104** may include one or more light emitting diodes (LEDs) that emit a light (e.g., an illumination light). When the input power is provided to the driver **102**, the output power that the driver **102** provides to the light source **104** is compatible with the light source **104** to enable the light source **104** to emit the light. When the power source **110** is turned off (i.e., when the input power is not available to the driver **102**), the light source **104** may continue to emit the light until the output power is adequately discharged from the driver **102** such that the voltage level on the connection **114** is no longer adequate to turn on the light source **104**.

In some example embodiments, when the input power from the power source **110** is turned off or otherwise becomes unavailable to the driver **102**, the driver **102** may continue to provide the output power on the connection **114**, for example, from one or more DC/output capacitors of the driver **102**. For example, when the input power is unavailable to the driver **102**, a portion of the output power may be discharged through the light source **104**, and a portion of the output power may be discharged through a power discharge path controlled by the light fade controller **106**.

In some example embodiments, when the input power becomes unavailable to the driver **102**, the light fade controller **106** may enable the power discharge path that can be used to discharge at least a portion of the output power from the driver **102**. To illustrate, the power source **110** may be electrically connected to the light fade controller **106** via an electrical connection **116** (e.g., one or more electrical wires). For example, the electrical connection **116** may be directly connected to the power source **110** or may be connected to the electrical connection **112**, which is connected to the power source **110**.

In some example embodiments, the light fade controller **106** may detect when the input power from the power source **110** is unavailable and enable the power discharge path in response to detecting that the input power is unavailable. For example, enabling the power discharge path can result in the output power from the driver **102** being discharged relatively quickly compared to the time that would take to discharge the output power just through the light source **104**. Discharging at least a portion of the output power through the discharge path can result in a relatively shorter fade time of the light emitted by the light source **104** when the input power from the power source **110** becomes unavailable to the driver **102**.

In some example embodiments, the power discharge path may include an electrical connection **118** (e.g., one or more electrical wires) that electrically connects the output of the driver **102** and the light fade controller **106**. In general, the power discharge path may provide a current path between the output of the driver **102** and an electrical ground and may include the connections **114**, **118**, and/or one or more components of the light fade controller **106** (as more clearly shown in FIG. **3**). As explained in more detail below, the light fade controller **106** may adjust the rate of power discharge through the power discharge path to a desired rate of power discharge. For example, the light fade controller **106** may adjust the rate of power discharge based on a user input provided to the light fade controller **106**. The light fade controller **106** may adjust the rate of power discharge through the power discharge path such that the light emitted by the light source **104** is fully turned off within or at a particular time after the input power from the power source **110** becomes unavailable to the driver **102**. In general, the light fade controller **106** may adjust the rate of power discharge such that the output power from the driver **102** is discharged relatively slow or fast.

In some example embodiments, the light fade controller **106** may operate using the output power from the driver **102** to enable and maintain the power discharge path even when the input power from the power source **110** is unavailable. To illustrate, the light fade controller **106** may operate using the output power from the driver **102** until the voltage level on the connection **114** becomes too low to allow continued operation. Because the voltage level required by the light fade controller **106** is lower than the voltage level required by the light source **104** to emit a light, the light fade controller **106** may continue to operate using the output power from the driver **102** even after the voltage level on the connection **114** becomes too low for the light source **104** to continue emitting the light. The relatively lower voltage level required by the light fade controller **106** compared to the voltage level required by light source **104** allows the light fade controller **106** to control the fade time of the light emitted by the light source **104** by enabling the power discharge path to discharge the output power from the driver **102** when the input power from the power source **110** becomes unavailable and by controlling the rate of discharge of the output power through the power discharge path.

When the input power is available to the driver **102**, the light fade controller **106** may disable or maintain as disabled the power discharge path. To illustrate, the light fade controller **106** may detect when the input power from the power source **110** is available and, in response, disable or maintain as disabled the power discharge path. Because the power discharge path is disabled when the input power is available, the output power from the driver **102** can be fully provided to the light source **104** via the connection **114**.

By enabling a power discharge path that facilitates the discharging of the output power from the driver **102**, the light fade controller **106** can enable a faster discharging of the output power from the driver **102** when the input power from the power source **110** becomes unavailable to the driver **102**. By controlling the rate of discharge of the output power, the light fade controller **106** can control the fade time of the light emitted by the light source **104** when the input power from the power source **110** becomes unavailable to the driver **102**. Controlling the fade time of the light emitted by the light source **104** can result in lights from multiple light fixtures of a lighting system that are commonly controlled (e.g., by a power switch) to have closely matching fade times or fade times that have desired variations. For example, a person can provide respective inputs to one or more light fixtures that include the light fade controller **106** such that the lights emitted by the one or more light fixtures are off at substantially the same time as a light emitted by a reference light fixture.

Although FIG. **1** shows the light fixture **100**, in some alternative embodiments, the light fade controller **106** may be used in another type of lighting device without departing from the scope of this disclosure. In some example embodiments, the driver **102** and the light fade controller **106** may be integrated in a single device without departing from the scope of this disclosure. In some alternative embodiments, the driver **102** and the light fade controller **106** may be standalone devices that may integrated in or coupled to a light fixture or another lighting device without departing from the scope of this disclosure. In some alternative embodiments, the driver unit **108** may be external to the light fixture **100** without departing from the scope of this disclosure. In some example embodiments, the components of the light fixture **100** may be connected using different connections than shown without departing from the scope of this disclosure.

FIG. **2** illustrates the light fixture **100** of FIG. **1** showing some components of the light fade controller **106** according to an example embodiment. Referring to FIGS. **1** and **2**, in some example embodiments, the driver **102** includes an input circuit **202**, a core circuit **204**, and an output circuit **206**. For example, the input circuit **202** may include a fuse, a common mode choke, a rectifier, and/or other components as readily understood by those of ordinary skill in the art with the benefit of the scope of this disclosure. The core circuit **204** may include a power management and/or other components that may control the output power provided by the output circuit **206**, which may include one or more DC/output capacitors **208** and other components such as a transformer, etc. The input circuit **202**, the core circuit **204**, and the output circuit **206** may be coupled and operated to generate output power on the connection **114** from the input power provided to the driver **102** via the connection **112** as can be readily understood by those of ordinary skill in the art with the benefit of the scope of this disclosure.

In some example embodiments, the light fade controller **106** may include an input power detection circuit **210**, an isolation unit **212**, and a power discharge circuit **214**. The input power detection circuit **210** may be electrically coupled to the power source **110** such that the input power detection circuit **210** can detect whether the input power from the power source **110** is provided to the driver **102**. For example, the input power detection circuit **210** may detect the voltage level on the connection **116** to determine whether the input power from the power source **110** is available to the driver **102**.

In some example embodiments, the power source **110** may provide AC power to the driver **102** via the connection **112**, and the input power detection circuit **210** may detect whether AC voltage is available to the driver **102**. FIG. **4** shows the input power detection circuit **210** of the light fade controller of FIGS. **1** and **2** according to an example embodiment, where the input terminal of the input power detection circuit **210** shown in FIG. **4** can be connected to the connection **116**, and the output terminal can be connected to the power discharge circuit **214** shown in FIGS. **1** and **2**. In some alternative embodiments, the light fade controller **106** may include a different input power detection circuit than the input power detection circuit **210** shown in FIG. **4** without departing from the scope of this disclosure.

In some example embodiments, the isolation unit **212** may electrically isolate the input power detection circuit **210** from the power discharge circuit **214**. For example, the isolation unit **212** may include an optocoupler that has an input coupled to the input power detection circuit **210** and an output coupled to the power discharge circuit **214**.

In some example embodiments, when the input power from the power source **110** becomes unavailable to the driver **102**, the power discharge circuit **214** may operate to enable the power discharge path to discharge at least a portion of the output power from the driver **102** through the discharge path. The power discharge path may include the connection **114** and one or more components of the power discharge circuit **214** as explained below in more detail with respect to FIG. **3**. The power discharge circuit **214** may enable the power discharge path when the input power detection circuit **210** indicates, through the isolation unit **212**, that the input power from the power source **110** is unavailable. When the power discharge path is enabled, at least a portion of the energy stored in the one or more capacitors **208** may be discharged through the power discharge path. When the input power from the power source **110** is available to the driver **102**, the power discharge circuit **214** may disable or maintain as disabled the power discharge path such that the output power from the driver **102** is not discharged through the power discharge path.

In some alternative embodiments, some of the components of the driver **102** and the light fade controller **106** may be integrated in a single device. In some alternative embodiments, the input circuit **202**, the core circuit **204**, and the output circuit **206** may each include other components instead of or in addition to the components described above. In some alternative embodiments, the driver **102** and the light fade controller **106** may each include different components than shown without departing from the scope of this disclosure. In some example embodiments, the components of the light fixture **100** may be connected using different connections than shown without departing from the scope of this disclosure.

FIG. **3** illustrates the light fixture **100** of FIGS. **1** and **2** and components of the light fade controller **106** of the light fixture **100** according to an example embodiment. Referring to FIGS. **1-3**, in some example embodiments, the light fade controller **106** includes the input power detection circuit **210** and the isolation unit **212**. The light fade controller **106** may also include a sawtooth wave generator **302**, an operational amplifier or comparator **304**, and a transistor **306** that operates as a switch and that is controlled by a control signal from the operational amplifier or comparator **304**. The transistor **306** may be coupled to the driver **102** and may be controlled by the control signal from the operational amplifier or comparator **304** to enable and disable the power discharge path that can be used to discharge the output power from the driver **102**. For example, the power discharge path may include the transistor **306** that is coupled to the output of the driver **102** via the electrical connections **114**, **118**. To illustrate, the transistor **306** may complete a current path to discharge the energy stored in the one or more capacitors **208** (shown in FIG. **2**).

In some example embodiments, the light fade controller **106** may also include a potentiometer **308**, shown in FIG. **3**, that has an adjustable resistance as can be readily understood by those of ordinary skill in the art. For example, the potentiometer **308** may be adjusted by a person to adjust the rate of power discharge of the output power through the power discharge path. For example, the control signal provided to the transistor **306** by the operational amplifier **304** may control the rate of power discharge through the transistor **306** based on the setting of the potentiometer **308**.

In some example embodiments, the isolation unit **212** may include an optocoupler including a transistor **316** that may be turned on or off depending on whether the input power detection circuit **210** detects the input power on the connection **116**. For example, the transistor **316** may be on when the input power is available and off when the input power is unavailable.

In some example embodiments, the transistor **316** may be coupled to a node **312** that is coupled to the potentiometer **308** and to a positive input of the operational amplifier **304**. A negative input of the operational amplifier **304** may be coupled to the output of the sawtooth wave generator **302** that generates a sawtooth waveform signal. FIG. **5** illustrates the sawtooth wave generator **302** of the light fade controller of FIGS. **1** and **2** according to an example embodiment. In some alternative embodiments, the power discharge circuit **214** may include a different sawtooth wave generator than the sawtooth wave generator **302** shown in FIG. **5** without departing from the scope of this disclosure.

In some example embodiments, the operational amplifier **304** may generate the control signal that is provided to the transistor **306** via an electrical connection **314** (e.g., one or more electrical wires) based on the voltage levels at the inputs of the operational amplifier **304**. To illustrate, because the transistor **316** is on when the input power from the power source **110** is available, the positive input of the operational amplifier **304** is coupled to ground when the input power is available. The positive input of the operational amplifier **304** being coupled to ground results in the control signal provided to the transistor **306** by the operational amplifier **304** being low. Because the transistor **306** is off when the control signal provided by the operational amplifier **304** is low, the power discharge path that includes the transistor **306** is disabled when the input power from the power source **110** is available on the connections **112**, **116**.

When the input power from the power source **110** is unavailable on the connections **112**, **116** as determined by the input power detection circuit **210**, the transistor **316** is turned off and the voltage level at the positive input of the operational amplifier **304** depends on the setting of the potentiometer **308**. For example, when the input power from the power source **110** is unavailable, the control signal generated by the operational amplifier **304** and provided to the transistor **306** via the connection **314** may be a pulse width modulation (PWM) signal that has a pulse width that depends on the setting of the potentiometer **308**. To illustrate, the potentiometer **308** may be adjusted by a user such that the PWM signal has a 100% duty cycle. When the PWM signal has a 100% duty cycle, the output power from the driver **102** may be discharged through the power discharge path at a maximum discharge rate. The potentiometer **308** may be adjusted by a user independent of whether the input power from the power source **110** is available to the driver **102**.

In some example embodiments, the pulse width of the PWM signal may also be adjusted such that the duty cycle of the PWM signal is closer to 0%, which may result in the output power from the driver **102** being discharged through the power discharge path at a very slow discharge rate. In general, the power discharge circuit **214** shown in FIG. **2** may control the pulse width of the PWM signal based on the setting of the potentiometer **308** such that the PWM signal has a duty cycle between 0% and 100% and to accordingly control the rate of power discharge through the power discharge path that includes the transistor **306**. The fade time of the light provided by the light source **104** is dependent on the rate of power discharge through the power discharge path and is accordingly adjusted by adjusting the potentiometer **308**.

In some example embodiments, the light fade controller **106** may include a regulator **310** that generates an output voltage Vcc from the output voltage provided by the driver **102** on the connections **114**, **118**. To illustrate, the regulator **310** may be coupled to the connection **118** that is electrically connected to the output of the driver **102**. The output voltage Vcc from the regulator **310** is provided to the components of the light fade controller **106** that require the voltage Vcc. In general, when the input power from the power source **110** turned off, the regulator **310** may continue to generate the output voltage Vcc at least until the voltage level on the connections **114**, **118** is below the voltage level that is required by the light source **104** to emit a light. For example, the voltage Vcc may have a voltage level (e.g., 5V) that enables the components of the light fade controller **106** to operate for a time period after the input power from the power source **110** is turned off. The operation of the light fade controller **106** after the input power is turned off allows the light fade controller **106** to provide the power discharge path to discharge the output power from the driver **102** upon the detection that the input power from the power source **110** is unavailable and to adjust the rate of power discharge.

In some example embodiments, the driver **102** and the light fade controller **106** may be included in the driver unit **108** as shown in FIGS. **1** and **2** without departing from the scope of this disclosure. In some example embodiments, the power discharge circuit **214** shown in FIG. **2** may include the sawtooth wave generator **302**, the operational amplifier **304**, the transistor **306**, and the potentiometer **308**. In some alternative embodiments, another type of variable resistor may be used instead of the potentiometer **308** without departing from the scope of this disclosure. In some example embodiments, the components of the light fade controller **106** may be integrated with the components of the driver **102** without departing from the scope of this disclosure. In some alternative embodiments, one or more of the components of the light fade controller **106** may be integrated into a single component without departing from the scope of this disclosure. In some alternative embodiments, the light fade controller **106** may include different components than shown without departing from the scope of this disclosure. In some example embodiments, the components of the light fade controller **106** may be connected using different connections than shown without departing from the scope of this disclosure.

Although particular embodiments have been described herein in detail, the descriptions are by way of example. The features of the embodiments described herein are representative and, in alternative embodiments, certain features, elements, and/or steps may be added or omitted. Additionally, modifications to aspects of the embodiments described herein may be made by those skilled in the art without departing from the scope of the following claims, the scope of which are to be accorded the broadest interpretation so as to encompass modifications and equivalent structures.

The invention claimed is:

**1**. A light fade controller (**106**), comprising:

an input power detection circuit (**210**) configured to detect whether an input power is available; and

a power discharge circuit (**214**) configured to:

enable a power discharge path (**118**, **306**) to discharge output power from a driver circuit (**102**) through the power discharge path in response to the input power detection circuit detecting that the input power is unavailable;

adjust a rate of power discharge through the power discharge path; and

wherein the power discharge circuit: (1) includes a switch (**306**) that is controlled by a pulse width modulation (PWM) control signal to enable and disable the power discharge path and to adjust the rate of power discharge through the power discharge path, wherein a pulse width of the PWM signal is adjusted to enable and disable the power discharge path and to adjust the rate of power discharge through the power discharge path, or (2) is configured to adjust the rate of power discharge based on a user input provided to the power discharge circuit.

**2**. The light fade controller of claim **1**, wherein the input power is alternating current (AC) power.

3. The light fade controller of claim 2, further comprising an isolation unit (212) configured to electrically isolate the input power from the power discharge circuit (214).

4. The light fade controller of claim 1, wherein the power discharge circuit is configured to disable or maintain as disabled the power discharge path in response to detecting that the input power is available.

5. A driver unit (108), comprising:

a driver circuit (102) configured to receive input power and generate, from the input power, output power compatible with a light source (104) of a lighting device (100); and

a light fade controller (106), comprising:

an input power detection circuit (210) configured to detect whether the input power is available to the driver circuit (102); and

a power discharge circuit (214) configured to enable a power discharge path (118, 306) to discharge output power from the driver circuit (102) through the power discharge path in response to the input power detection circuit (210) detecting that the input power is unavailable to the driver circuit (102) and to adjust a rate of power discharge through the power discharge path; and

wherein the power discharge circuit; (1) includes a switch that is controlled by a width modulation (PWM) control signal to enable and disable the power discharge path and to adjust the rate of power discharge through the power discharge path, and wherein a pulse width of the PWM signal is adjusted to enable and disable the power discharge path and to adjust the rate of power discharge through the power discharge path, or (2) is configured to adjust the rate of power discharge based on a user input provided to the power discharge circuit.

6. The driver unit of claim 5, wherein the input power is alternating current (AC) power.

7. The driver unit of claim 6, wherein the light fade controller further comprises an isolation unit configured to electrically isolate the input power from the power discharge circuit.

8. The driver unit of claim 5, wherein the power discharge circuit is configured to disable or maintain as disabled the power discharge path in response to the input power detection circuit (210) detecting that the input power is available to the driver circuit.

9. The driver unit of claim 5, wherein the power discharge circuit (214) operates using the output power to enable the power discharge path.

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