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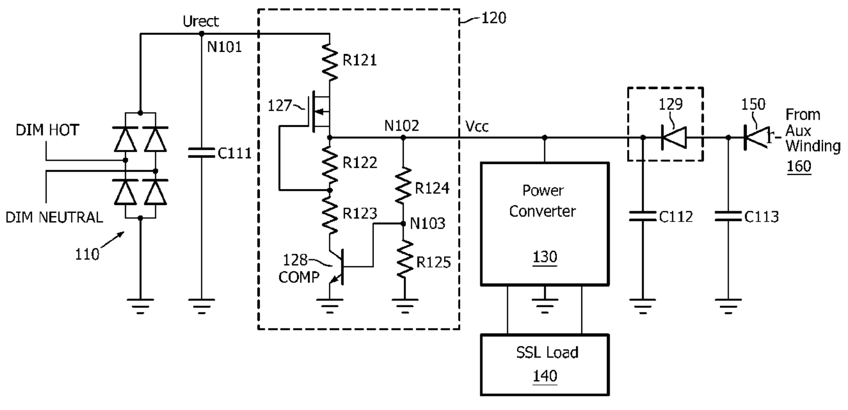

FIG. 1

(57) Abstract: A device enables rapid start-up of a power converter during a start-up period, the power converter controlling power to a solid state lighting load. The device includes a low impedance path formed temporarily between a rectified voltage node and a power converter voltage node for charging the power converter during the start-up period. The device further includes a diode connected between the power converter and an auxiliary winding. The diode has a cathode connected to the ground voltage through a first capacitor having a small bypass capacitance and an anode connected to the ground voltage through a second capacitor having a large bulk capacitance. The first capacitor is charged and the second capacitor is not charged while the low impedance path is formed during the start-up period.

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RAPID START-UP CIRCUIT FOR SOLID STATE LIGHTING SYSTEM

Technical Field

[0001] The present invention is directed generally to rapid start-up circuits for solid state lighting systems. More particularly, various inventive apparatuses and methods disclosed herein relate to comparatively low voltage circuits for use with dimming circuits in solid state lighting systems.

Background

[0002] Digital or solid state lighting technologies, i.e., illumination based on semiconductor light sources, such as light-emitting diodes (LEDs) and organic light-emitting diodes (OLEDs), offer a viable alternative to traditional fluorescent, high-intensity discharge (HID), and incandescent lamps. Functional advantages and benefits of LEDs include high energy conversion and optical efficiency, durability, lower operating costs, and many others. Recent advances in LED technology have provided efficient and robust full-spectrum lighting sources that enable a variety of lighting effects in many applications. Some of the fixtures embodying these sources feature a lighting module, including one or more LEDs capable of producing white light and/or different colors of light, e.g., red, green and blue, as well as a controller or processor for independently controlling the output of the LEDs in order to generate a variety of colors and color-changing lighting effects, for example, as discussed in detail in U.S. Patent Nos. 6,016,038, 6,21 1,626, and 7,014,336 incorporated herein by reference.

[0003] Many lighting applications make use of dimmers. While conventional dimmers work well with incandescent lamps, problems often occur when these dimmers are used with other types of electronic lamps, including compact fluorescent lamp (CFL), low voltage halogen lamps using electronic transformers and solid state lighting (SSL) lamps, such as LEDs and OLEDs. Low voltage SSL units using electronic transformers, in particular, may be dimmed using special dimmers, such as electric low voltage (ELV) type dimmers or resistive-capacitive (RC) dimmers, for example.

[0004] Dimmers typically include an electronic switch. When the switch is closed (turned on), a voltage is applied to the output and when the switch is open (turned off), no voltage is applied to the output. Different types of electronic switches may be used in conventional dimmers. For example, triacs may be used, which require a minimum current to stay on. This is the so-called holding current. Low-wattage lamps, such as LED lamps, often fail to draw this minimum current at low dim levels, causing the triac to switch incorrectly causing flicker. Other dimmers use metal-oxide semiconductor field-effect transistors (MOSFETs) or insulated gate bipolar transistors (IGBTs) as the electronic switch. These switches have no minimum current requirement, and thus LED lamps typically work better with these non-triac based dimmers.

[0005] Conventional dimmers typically chop a portion of each waveform (sine wave) of the mains voltage signal and pass the remainder of the waveform to the lighting fixture. A leading edge or forward-phase dimmer chops the leading edge of the voltage signal waveform. A trailing edge or reverse-phase dimmer chops the trailing edge of the voltage signal waveform. Electronic loads, such as LED drivers, typically operate better with trailing edge dimmers.

[0006] Unlike incandescent and other resistive lighting devices which respond naturally without error to a chopped waveform produced by a dimmer, LED and other SSL units or fixtures have a noticeable delay from when a user switches on the light fixture to when the light actually turns on. This delay from when the physical power switch on the SSL unit or fixture is turned on to when light is first seen from the fixture may be undesirably long. The cause of this delay is the time it takes for the power converter to have enough voltage to start up and begin converting power from the unrectified line voltage to power the SSL unit or fixture according to the dimmer setting. The time delay is determined by various factors, such as the available rectified voltage (Urect), e.g., as determined by the chopped waveform of the mains voltage signal based on dimmer setting, the impedance from the node Urect to the node Vcc, which supplies power to the power converter integrated circuit (IC), and the capacitance from the node Vcc to ground.

[0007] To address this delay, so-called "instant start" circuits have been developed. However, relatively low dimmer settings used in combination with instant start circuits still result in noticeable delay from the time the switch is flipped to turn on the SSL unit or fixture to the time light is seen. For example, an instant start circuit may be passive, e.g., consisting of an RC circuit. Generally, the lower the impedance of the start-up network, the faster the power converter will turn on. However, with the passive RC start-up network, steady state power loss increases with faster turn-on time, which results in lower power supply efficiency and thus lower overall fixture efficacy (e.g., lumens per watt).

[0008] Thus, there is a need in the art for an instant start circuit that that provides sufficient power to the power converter IC of a solid-state lighting unit or fixture over a range of dim levels, and particularly at comparatively low dim levels.

Summary

[0009] The present disclosure is directed to inventive methods and devices for providing rapid start capability of a power converter for solid state lighting units and fixtures at low dimmer settings.

[0010] Generally, in one aspect, a device is provided for enabling rapid start-up of a power converter during a start-up period, the power converter controlling power to a solid state lighting load. The device includes a low impedance path formed temporarily between a rectified voltage node and a power converter voltage node for charging the power converter during the start-up period. The device further includes a diode connected between the power converter and an auxiliary winding, the diode including a cathode connected to the ground voltage through a first capacitor having a small bypass capacitance and an anode connected to the ground voltage through a second capacitor having a large bulk capacitance. The first capacitor is charged and the second capacitor is not charged while the low impedance path is formed during the start-up period.

[0011] In another aspect, a device is provided for enabling rapid start-up of a power converter during a start-up period, the power converter controlling power to a solid state lighting load. The device includes a transistor, a first diode and a second diode. The transistor is connected between a rectified voltage node and the power converter, the transistor selectively providing a low impedance path from the rectified voltage node to the power converter when the transistor is turned on during the start-up period. The first diode includes a cathode connected to the transistor and the rectified voltage node and an anode connected to a ground voltage. The second diode is connected between an auxiliary winding and the power converter, the second diode including a cathode connected to the ground voltage through a first capacitor having a small bypass capacitance and an anode connected to the ground voltage through a second capacitor having a large bulk capacitance. The first capacitor is charged and the second capacitor is not charged while the transistor is turned on at startup.

[0012] In yet another aspect, a device is provided for enabling rapid start-up of a power converter during a start-up period, the power converter controlling power to a solid state lighting load. The device includes a first transistor, a second transistor and a diode. The first transistor is connected between a rectified voltage node and a power converter node, which provides a voltage powering the power converter, the first transistor selectively providing a low impedance path from the rectified voltage node to the power converter node when the first transistor is turned on during the start-up period. The second transistor is connected between the first transistor and a ground voltage. The diode is connected between an auxiliary winding and the power converter node, the diode including a cathode connected to the ground voltage through a first capacitor having a small bypass capacitance and an anode connected to the ground voltage through a second capacitor having a large bulk capacitance. The second transistor is turned off when the voltage at the power converter node is less than a steady state value during the start-up period, turning on the first transistor to provide the low impedance path, and charging the first capacitor, but not the second capacitor. The second transistor is turned on when the voltage at the power converter node reaches the steady state value at the end of the start-up period, turning off the first transistor to remove the low impedance path, and charging the first capacitor and the second capacitor.

[0013] As used herein for purposes of the present disclosure, the term "LED" should be understood to include any electroluminescent diode or other type of carrier injection/junction-based system that is capable of generating radiation in response to an electric signal. Thus, the term LED includes, but is not limited to, various semiconductor-based structures that emit light in response to current, light emitting polymers, organic light emitting diodes (OLEDs), electroluminescent strips, and the like. In particular, the term LED refers to light emitting diodes of all types (including semi-conductor and organic light emitting diodes) that may be configured to generate radiation in one or more of the infrared spectrum, ultraviolet spectrum, and various portions of the visible spectrum (generally including radiation wavelengths from approximately 400 nanometers to approximately 700 nanometers). Some examples of LEDs include, but are not limited to, various types of infrared LEDs, ultraviolet LEDs, red LEDs, blue LEDs, green

LEDs, yellow LEDs, amber LEDs, orange LEDs, and white LEDs (discussed further below). It also should be appreciated that LEDs may be configured and/or controlled to generate radiation having various bandwidths (e.g., full widths at half maximum, or FWHM) for a given spectrum (e.g., narrow bandwidth, broad bandwidth), and a variety of dominant wavelengths within a given general color categorization.

[0014] For example, one implementation of an LED configured to generate essentially white light (e.g., LED white lighting fixture) may include a number of dies which respectively emit different spectra of electroluminescence that, in combination, mix to form essentially white light. In another implementation, an LED white light fixture may be associated with a phosphor material that converts electroluminescence having a first spectrum to a different second spectrum. In one example of this implementation, electroluminescence having a relatively short wavelength and narrow bandwidth spectrum "pumps" the phosphor material, which in turn radiates longer wavelength radiation having a somewhat broader spectrum.

[0015] It should also be understood that the term LED does not limit the physical and/or electrical package type of an LED. For example, as discussed above, an LED may refer to a single light emitting device having multiple dies that are configured to respectively emit different spectra of radiation (e.g., that may or may not be individually controllable). Also, an LED may be associated with a phosphor that is considered as an integral part of the LED (e.g., some types of white light LEDs). In general, the term LED may refer to packaged LEDs, non-packaged LEDs, surface mount LEDs, chip-on-board LEDs, T-package mount LEDs, radial package LEDs, power package LEDs, LEDs including some type of encasement and/or optical element (e.g., a diffusing lens), etc.

[0016] The term "light source" should be understood to refer to any one or more of a variety of radiation sources, including, but not limited to, LED-based sources (including one or more LEDs as defined above), incandescent sources (e.g., filament lamps, halogen lamps), fluorescent sources, phosphorescent sources, high-intensity discharge sources (e.g., sodium vapor, mercury vapor, and metal halide lamps), lasers, other types of electroluminescent sources, pyro-luminescent sources (e.g., flames), candle-luminescent sources (e.g., gas mantles, carbon arc radiation sources), photo-luminescent sources (e.g., gaseous discharge sources), cathode luminescent sources using electronic satiation, galvano-luminescent sources, crystalloluminescent sources, kine-luminescent sources, thermo-luminescent sources, triboluminescent sources, sonoluminescent sources, radioluminescent sources, and luminescent polymers.

[0017] A given light source may be configured to generate electromagnetic radiation within the visible spectrum, outside the visible spectrum, or a combination of both. Hence, the terms "light" and "radiation" are used interchangeably herein. Additionally, a light source may include as an integral component one or more filters (e.g., color filters), lenses, or other optical components. Also, it should be understood that light sources may be configured for a variety of applications, including, but not limited to, indication, display, and/or illumination. An "illumination source" is a light source that is particularly configured to generate radiation having a sufficient intensity to effectively illuminate an interior or exterior space. In this context, "sufficient intensity" refers to sufficient radiant power in the visible spectrum generated in the space or environment (the unit "lumens" often is employed to represent the total light output from a light source in all directions, in terms of radiant power or "luminous flux") to provide ambient illumination (i.e., light that may be perceived indirectly and that may be, for example, reflected off of one or more of a variety of intervening surfaces before being perceived in whole or in part).

[0018] The term "lighting fixture" is used herein to refer to an implementation or arrangement of one or more lighting units in a particular form factor, assembly, or package. The term "lighting unit" is used herein to refer to an apparatus including one or more light sources of same or different types. A given lighting unit may have any one of a variety of mounting arrangements for the light source(s), enclosure/housing arrangements and shapes, and/or electrical and mechanical connection configurations. Additionally, a given lighting unit optionally may be associated with (e.g., include, be coupled to and/or packaged together with) various other components (e.g., control circuitry) relating to the operation of the light source(s). An "LED-based lighting unit" refers to a lighting unit that includes one or more LED-based light sources as discussed above, alone or in combination with other non LED-based light sources. A "multi-channel" lighting unit refers to an LED-based or non LED-based lighting unit that includes at least two light sources configured to respectively generate different spectrums of radiation, wherein each different source spectrum may be referred to as a "channel" of the multi-channel lighting unit.

[0019] The term "controller" is used herein generally to describe various apparatus relating to the operation of one or more light sources. A controller can be implemented in numerous ways (e.g., such as with dedicated hardware) to perform various functions discussed herein. A "processor" is one example of a controller which employs one or more microprocessors that may be programmed using software (e.g., microcode) to perform various functions discussed herein. A controller may be implemented with or without employing a processor, and also may be implemented as a combination of dedicated hardware to perform some functions and a processor (e.g., one or more programmed microprocessors and associated circuitry) to perform other functions. Examples of controller components that may be employed in various embodiments of the present disclosure include, but are not limited to, conventional microprocessors, application specific integrated circuits (ASICs), and field-programmable gate arrays (FPGAs).

[0020] It should be appreciated that all combinations of the foregoing concepts and additional concepts discussed in greater detail below (provided such concepts are not mutually inconsistent) are contemplated as being part of the inventive subject matter disclosed herein. In particular, all combinations of claimed subject matter appearing at the end of this disclosure are contemplated as being part of the inventive subject matter disclosed herein. It should also be appreciated that terminology explicitly employed herein that also may appear in any disclosure incorporated by reference should be accorded a meaning most consistent with the particular concepts disclosed herein.

Brief Description of the Drawings

[0021] In the drawings, like reference characters generally refer to the same or similar parts throughout the different views. Also, the drawings are not necessarily to scale, emphasis instead generally being placed upon illustrating the principles of the invention.

[0022] FIG. 1 is a block diagram showing a rapid start circuit, according to a first representative embodiment.

[0023] FIG. 2 is a block diagram showing a rapid start circuit, according to a second representative embodiment.

Detailed Description

[0024] In the following detailed description, for purposes of explanation and not limitation, representative embodiments disclosing specific details are set forth in order to provide a thorough understanding of the present teachings. However, it will be apparent to one having ordinary skill in the art having had the benefit of the present disclosure that other embodiments according to the present teachings that depart from the specific details disclosed herein remain within the scope of the appended claims. Moreover, descriptions of well-known devices and methods may be omitted so as to not obscure the description of the representative embodiments. Such methods and devices are clearly within the scope of the present teachings.

[0025] Applicants have recognized and appreciated that it would be beneficial to provide a circuit capable of reducing the delay between activating a switch of a solid state light unit or fixture and the turn-on time, particularly at low dimmer settings. In other words, Applicants appreciated the need to provide rapid start capability of a power converter for solid state lighting units and fixtures at low dimmer settings.

[0026] FIG. 1 is a block diagram showing a rapid start circuit for powering a solid state lighting system, for example, a lighting system employing one or more LED light sources, according to a representative embodiment. Referring to FIG. 1, rapid start circuit 120 includes first (depletion) transistor 127, second transistor 128, representative resistors 121-125 and diode 129 (shown separately). For purposes of the following explanation, the first transistor 127 is a field-effect transistor (FET) and the second transistor is a bipolar junction transistor (BJT), although other types of transistors may be implemented without departing from the scope of the present teachings. The rapid start circuit 120 provides voltage Vcc to power converter 130 (or power converter IC) so that the power converter 130 can start up more quickly during a start-up period, and begin delivering power from the mains to the SSL load 140.

[0027] The start-up period is the time it takes for auxiliary winding 160 to be fully charged and for the voltage Vcc to reach a steady state value. The auxiliary winding 160 provides voltage to Vcc node N102 when the power converter 130 is in steady state operation. However, the auxiliary winding 160 cannot be used to start up the power converter 130 when the power converter 130 is in the off state, so some other means, such as the rapid start circuit 120, is provided. The auxiliary winding 160 is typically taken as an extra winding off of the main power magnetic which the power converter 130 uses to convert power. The auxiliary winding 160 therefore uses a small fraction of the energy in the main winding to power the power converter 130. The SSL load 140 may be a solid state light unit or fixture or other system, for example.

[0028] The rapid start circuit 120 receives (dimmed) rectified voltage Urect through diode bridge or bridge rectifier 110 from the dimmer (not shown) via Dim Hot and Dim Neutral. When a dimming setting has been selected, the rectified voltage Urect has leading edge or trailing edge chopped waveforms, the extent of which is determined by the selected extent of dimming, where low dimmer settings result in more significant waveform chopping and thus a lower RMS rectified voltage Urect. A rectified voltage Urect node N101 may be coupled to ground voltage through capacitor CI 11 (e.g., about 0.1 μF) in order to filter the switching current of the power converter IC. Notably, the various values provided throughout the description are illustrative, and may be determined depending on the particular situation or application specific design requirements of various implementations, such as use of U.S. voltages, E.U. voltages, or some other voltages, as would be apparent to one skilled in the art.

[0029] The rectified voltage Urect is connected through bridge rectifier 110 to a dimmer (not shown) via lines DIM hot and DIM neutral. The dimmer initially receives (undimmed) unrectified voltage from a power source via the power mains. Generally, the unrectified voltage is an AC line voltage signal having a voltage value, e.g., between about 90VAC and about 277VAC, and corresponding substantially sinusoidal waveforms. The dimmer includes an adjuster, which enables a dimming setting to be variably selected, e.g., manually by a user or automatically by a processor or other setting selection system. In an embodiment, the adjuster enables settings ranging from about 20 to 90 percent of the maximum light level of the SSL load 140. Also, in various embodiments, the dimmer is a phase chopping (or phase cutting) dimmer, which chops either the leading edges or trailing edges of the input voltage waveforms, thereby reducing the amount of power reaching the SSL load 140. For purposes of explanation, it is assumed the dimmer is a trailing edge dimmer, which cuts a variable amount of the trailing edges of the unrectified sinusoidal waveforms.

[0030] Generally, the rapid start circuit 120 temporarily creates a low impedance path from Urect node N101 to Vcc node N102 during the start-up period, which occurs when the auxiliary winding 160 is not yet fully charged (for powering the power converter 130) and the voltage Vcc has not yet reached a steady state value. For example, when the SSL load 140 is turned-on (e.g., via the dimmer adjuster or other physical switch), the initial voltage of the auxiliary winding 160 is zero, and will remain zero until the power converter 130 has a chance to start up during the start-up period. Power for start-up of the power converter 130 is drawn through R121 (e.g., about 22kQ) and the depletion first transistor 127 of the rapid start circuit 120 to charge capacitors CI 12 and CI 13. After the power converter 130 has started up, the auxiliary winding 160 provides the voltage Vcc to the power converter 130 through diode 150 and the first transistor 127 is made high impedance through activation of the second transistor 128, as discussed a below. The capacitor CI 12 provides a small bypass capacitance (e.g., about 0.1 μF) connected between Vcc node N102 and ground in order to shunt high frequency noise, and the capacitor CI 13 provides a large bulk capacitance (e.g., about 10μF) connected between Vcc node N 102 and ground, in order to provide lower frequency filtering and temporary hold up.

[0031] More particularly, at the beginning of the start-up period, a COMP signal received at the base of the second transistor 128 is initially low. In the depicted representative embodiment, the second transistor 128 also includes a collector connected to resistor R123 (e.g., about lOOkH) and an emitter connected to ground voltage. The low COMP signal turns off the second transistor 128, and thus the second transistor 128 is effectively open circuited. In the depicted embodiment, the COMP signal is provided through node N103, which is connected to voltage Vcc at Vcc node N102 through resistor R124 (e.g., about lOOkQ) and to the ground voltage through resistor 125 (e.g., about lOOkQ). The COMP signal is initially low because the voltage Vcc is low, since the rectified voltage Urect has not charged the auxiliary winding 160, and thus the voltage Vcc at Vcc node N102 is not yet at the steady state value. Because the second transistor 128 is turned off, the gate of the depletion first transistor 127 is connected to the source of the depletion first transistor 127, for example, through resistor R122 (e.g., about lOOkQ). In this state, the impedance of the depletion first transistor 127 is low. A drain of the first transistor 127 is connected to Urect node N101 through resistor R121 (e.g., about 22kQ).

[0032] When the system is powered up, the rectified voltage Urect is high, and the voltage Vcc begins to charge through the resistor R121 and the first transistor 127. When the voltage Vcc is charged to the necessary voltage, the power converter 130 activates to power the SSL load 140, and the COMP signal is brought high. The high COMP signal turns on the second transistor 128, which connects the gate of the first transistor 127 to ground voltage through the resistor R123. In this state, the first transistor 127 is turned off, and its impedance becomes high, which effectively disconnects the rectified voltage Urect at Urect node N101 from the Vcc node N102. In other words, when the COMP signal is low, the rectified voltage Urect at Urect node N101 is connected to the Vcc node N202 through a low impedance, and when the COMP signal high, this low impedance is disconnected.

[0033] In addition, the rapid start circuit 120 includes the diode 129, which separates the large bulk capacitor CI13 from the small bypass capacitor CI12, thereby reducing the total capacitance from Vcc node N102 to ground during the start-up transient. In an embodiment, the diode 129 includes an anode connected to ground through the capacitor CI13 and a cathode connected to ground through the capacitor CI12.

[0034] When the mechanical switch on the dimmer (not shown) is turned on, the voltage from the auxiliary winding 160 is at or near ground voltage, assuming the SSL load 140 has been off for a sufficiently long time, and the diode 129 is reverse biased. Because the COMP signal is initially low, the second transistor 128 is turned off, and the gate and source of the first transistor 127 are connected, current is allowed to flow from rectified voltage Urect node N201 through the resistor R121 and the first transistor 127 to Vcc node N102, as discussed above, initially charging only the capacitor CI12 and not the capacitor CI13, which has been effectively removed from the circuit by the diode 129. Because the capacitor CI12 is a small value capacitor used for bypassing Vcc node N202, the rapid start circuit 120 is able to charge the capacitor CI12 to the operating voltage of the power converter 130 quickly, even when the rectified voltage Urect at Urect node N101 is very small, e.g., when the dimmer is at its lowest setting.

[0035] The large bulk capacitor C213 is not removed when Vcc is at the steady state voltage value, but only during the start-up period when the voltage at the auxiliary winding 160 is low. That is, in steady state, the diode 129 conducts, enabling capacitor CI13 to be connected to the voltage Vcc at Vcc node N102, providing the ripple reducing benefits of a large bulk capacitor. In addition, once the power converter 130 has started running, the COMP signal goes high and the second transistor 128 is switched on, causing the first transistor 127 to turn off and thus effectively disconnecting the rectified voltage Urect at Urect node N101 from the Vcc node N102, as discussed above.

[0036] Accordingly, the diode 129 of the rapid start circuit 120 effectively switches out the large bulk capacitance of the capacitor CI13 during the start up transient, but allows it to be connected during steady state operation. By disconnecting the capacitor CI13 during start-up, the voltage Vcc can be charged up faster, enabling rapid start even when the rectified voltage Urect is very low, such as when a dimmer is at its lowest setting.

[0037] In various embodiments, the dimmer may be a two- or three-wire electronic low-voltage (ELV) dimmer, for example, such as Lutron Diva DVELV-300 dimmer, available from Lutron Electronics Co., Inc. The SSL load 140 may be an LED or OLED lighting unit or lighting system, for example. The various components shown in FIG. 1 may be arranged in different pre-packaged configurations that may differ from the depicted grouping. For example, the bridge rectifier 110, the rapid start circuit 120, the power converter 130 and the SSL load 140 may be packaged together in one product, such as EssentialWhite™, lighting fixture, available from Philips Color Kinetics. Various embodiments may include any type of the dimmer, lighting system and/or packaging, without departing from the scope of the present teachings.

[0038] The dimmer provides the dimmed rectified voltage (e.g., having chopped waveforms) to the power converter 130 though the bridge rectifier 100 and the rapid start circuit 120. The power converter 130 may include structure and functionality described, for example, in U.S. Patent No. 7,256,554, to Lys, issued August 14, 2007, the subject matter of which is hereby incorporated by reference.

[0039] The power converter 130 may be constructed of any combination of hardware, firmware or software architectures, without departing from the scope of the present teachings. For example, in various embodiments, the power converter 130 may implemented as a controller, such as a microprocessor, ASIC, FPGA, and/or microcontroller, such as an L6562 PFC controller, available from ST Microelectronics.

[0040] As stated above, when the dimmer is adjusted to a low setting, resulting in an RMS voltage of the dimmer output being fairly low (e.g., about 35V or less), there would typically not be enough energy transferred to the power magnetic for the auxiliary winding 160 to power the power converter 130, resulting in shut down. However, in accordance with the present embodiment, the low dimmer level is detected by the failing of voltage Vcc via the divider formed by the resistors R124 and R125, and the rapid start circuit 120 is activated via the COMP signal. Once the rapid start circuit 120 is activated, the power converter 130 is supplied from the rectified mains through the resistor R121 and the depletion first transistor 127 (e.g., implemented as a FET). When the first transistor 127 is switched in, the power converter 130 is able to run even during low dimmer levels, preventing negative start-up effects, such as delay and flickering. In other embodiments, the low dimmer level may be detected by an entity not depicted in FIG. 1, such as a controller or microcontroller, and the COMP signal may be controlled by this entity to activate or deactivate the rapid start circuit 120, as needed.

[0041] It is understood that, although representative values have been provided above for purposes of discussion, the values of the capacitors CI 11-Cl 13 and the resistors R121-R125 are determined depending on the particular situation or application specific design requirements of various implementations, as would be apparent to one skilled in the art.

[0042] FIG. 2 is a block diagram showing a rapid start circuit for powering a solid state lighting system, according to another representative embodiment. Referring to FIG. 2, rapid start circuit 220 includes transistor 225, first diode 226, representative resistors 2 11-212 and second diode 227 (shown separately). For purposes of the following explanation, the transistor 225 is a BJT and the first diode is a zener diode, although other types of transistors and/or diodes may be implemented without departing from the scope of the present teachings. As discussed above with respect to the rapid start circuit 120 in FIG. 1, the rapid start circuit 220 provides voltage Vcc to power converter 230 (or power converter IC) for powering SSL load 240 during a start-up period, until auxiliary winding 260 is fully charged and the voltage Vcc has a steady state value.

[0043] The rapid start circuit 220 receives (dimmed) rectified voltage Urect through diode bridge or bridge rectifier 210 from the dimmer via Dim Hot and Dim Neutral. When a dimming setting has been selected, the rectified voltage Urect has leading edge or trailing edge chopped waveforms, the extent of which is determined by the selected dimming setting, where low dimmer settings result in more significant waveform chopping and thus a lower RMS rectified voltage Urect. A rectified voltage Urect node N201 may be coupled to ground voltage through capacitor C21 1 (e.g., about 0.1 μF) in order to filter the switching current of the power converter.

[0044] The rectified voltage Urect is provided through the bridge rectifier 210 from a dimmer (not shown) via lines DIM hot and DIM neutral. The dimmer initially receives (undimmed) unrectified voltage from a power source via the power mains. Generally, the unrectified voltage is an AC line voltage signal having a voltage value, e.g., between about 90VAC and about 277VAC, and corresponding substantially sinusoidal waveforms. The dimmer includes an adjuster, which enables a dimming setting to be variably selected, e.g., manually by a user or automatically by a processor or other setting selection system. In an embodiment, the adjuster enables settings ranging from about 20 to 90 percent of the maximum light level of the SSL load 240, for example. Also, in various embodiments, the dimmer is a phase chopping (or phase cutting) dimmer, which chops either the leading edges or trailing edges of the input voltage waveforms, thereby reducing the amount of power reaching the SSL load 240.

[0045] The rapid start circuit 220 is particularly effective at very low dimming settings. According to the depicted representative embodiment, even when the rectified voltage Urect at Urect node N201 is very low (e.g., at the lowest dimmer setting), the rapid start circuit 220 avoids visible delay by lowering the capacitance from the voltage Vcc at Vcc node N202 to ground voltage during the start-up period, in addition to lowering resistance from the rectified voltage Urect at Urect node N201 to the voltage Vcc at Vcc node N202 during the start-up period. After the power converter 230 has started up, the auxiliary winding 260 provides the voltage Vcc to the power converter 230 through second diode 227 and third diode 250, discussed below.

[0046] More particularly, the rapid start circuit 220 shown in FIG. 2 includes the first diode 226 having a cathode connected to node N203 and an anode connected to a ground voltage. The rapid start circuit 220 also includes the transistor 225, having a base connected to node N203, a collector connected to Urect node N201 (rectified voltage Urect) through resistor R212 (e.g., about 5kQ), and an emitter connected to Vcc node N202 (voltage Vcc). Node N203 is also connected to Urect node N201 through resistor R21 1 (e.g., about 200kQ). The resistor R21 1 enables enough current to flow through the first diode 226 to keep the base of the transistor 225 slightly below the steady state voltage value of Vcc at Vcc node N202 when the voltage Vcc has been fully charged. However, when the voltage Vcc is below the voltage at the base of the transistor 225, such as during start up, the transistor 225 turns on, providing a low impedance path from the rectified voltage Urect to the voltage Vcc through the resistor R2 12 and the transistor 225, thus lowering the impedance from the rectified voltage node Urect N201 to the Vcc node N202 during the start-up transient, prior to the charging of the auxiliary winding 260.

[0047] In addition, rapid start circuit 220 includes the second diode 227, which separates the large bulk capacitance, capacitor C213 (e.g., about 10μF), from the small bypass capacitance, capacitor C212 (e.g., about 0.1 μF), thereby reducing the total capacitance from Vcc node N202 to ground during the start-up transient. In an embodiment, the second diode 227 includes an anode connected to ground through the capacitor C213 and a cathode connected to ground through the capacitor C212.

[0048] When the mechanical switch on the dimmer (not shown) is turned on, the voltage from the auxiliary winding 260 is at or near ground voltage, assuming the SSL load 240 has been off for a sufficiently long time, and the second diode 227 is reverse biased. Because the resistor R21 1 biases the first diode 226, the transistor 225 turns on, allowing current to flow from rectified voltage Urect node N201 through the resistor R212 and the transistor 225 to Vcc node N202, as discussed above, initially charging only the capacitor C212 and not the capacitor C213, which has been effectively removed from the circuit by the second diode 227. Because the capacitor C212 is a small value capacitor used for bypassing Vcc node N202, the rapid start circuit 220 is able to charge the capacitor C212 to the operating voltage of the power converter 230 quickly, even when the rectified voltage Urect at Urect node N201 is very small, e.g., when the dimmer is at its lowest setting.

[0049] The large bulk capacitor C2 13 is not removed when Vcc is at the steady state voltage value, but only during the start-up period when the voltage at the auxiliary winding 260 is low. That is, in steady state, second diode 227 conducts, enabling the capacitor C213 to be connected to the voltage Vcc at Vcc node N202, providing the ripple reducing benefits of a large bulk capacitor. In addition, once the power converter 230 has started running, the transistor 225 is switched off because the first diode 226 is chosen to have a breakdown voltage slightly below the steady state voltage Vcc. In this manner, the second diode 227 effectively switches out the large bulk capacitance of the capacitor C2 13 during the start up transient, but allows it to be connected during steady state operation. By disconnecting the capacitor C213 during start-up, the voltage Vcc can be charged up faster, enabling rapid start even when the rectified voltage Urect is very low, such as when a dimmer is at its lowest setting.

[0050] It is understood that, although some representative values have been provided above for purposes of discussion, the values of the capacitors C21 1-C213 and the resistors R21 1-R2 12 are determined depending on the particular situation or application specific design requirements of various implementations, as would be apparent to one skilled in the art.

[0051] While multiple inventive embodiments have been described and illustrated herein, those of ordinary skill in the art will readily envision a variety of other means and/or structures for performing the function and/or obtaining the results and/or one or more of the advantages described herein, and each of such variations and/or modifications is deemed to be within the scope of the inventive embodiments described herein.

[0052] More generally, those skilled in the art will readily appreciate that all parameters, dimensions, materials, and configurations described herein are meant to be exemplary and that the actual parameters, dimensions, materials, and/or configurations will depend upon the specific application or applications for which the inventive teachings is/are used. Those skilled in the art will recognize, or be able to ascertain using no more than routine experimentation, many equivalents to the specific inventive embodiments described herein. It is, therefore, to be understood that the foregoing embodiments are presented by way of example only and that, within the scope of the appended claims and equivalents thereto, inventive embodiments may be practiced otherwise than as specifically described and claimed. Inventive embodiments of the present disclosure are directed to each individual feature, system, article, material, kit, and/or method described herein. In addition, any combination of two or more such features, systems, articles, materials, kits, and/or methods, if such features, systems, articles, materials, kits, and/or methods are not mutually inconsistent, is included within the inventive scope of the present disclosure.

[0053] All definitions, as defined and used herein, should be understood to control over dictionary definitions, definitions in documents incorporated by reference, and/or ordinary meanings of the defined terms.

[0054] The indefinite articles "a" and "an," as used herein in the specification and in the claims, unless clearly indicated to the contrary, should be understood to mean "at least one."

[0055] The phrase "and/or," as used herein in the specification and in the claims, should be understood to mean "either or both" of the elements so conjoined, i.e., elements that are conjunctively present in some cases and disjunctively present in other cases. Multiple elements listed with "and/or" should be construed in the same fashion, i.e., "one or more" of the elements so conjoined. Other elements may optionally be present other than the elements specifically identified by the "and/or" clause, whether related or unrelated to those elements specifically identified. Thus, as a non-limiting example, a reference to "A and/or B", when used in conjunction with open-ended language such as "comprising" can refer, in one embodiment, to A only (optionally including elements other than B); in another embodiment, to B only (optionally including elements other than A); in yet another embodiment, to both A and B (optionally including other elements); etc.

[0056] As used herein in the specification and in the claims, "or" should be understood to have the same meaning as "and/or" as defined above. For example, when separating items in a list, "or" or "and/or" shall be interpreted as being inclusive, i.e., the inclusion of at least one, but also including more than one, of a number or list of elements, and, optionally, additional unlisted items. Only terms clearly indicated to the contrary, such as "only one of or "exactly one of," or, when used in the claims, "consisting of," will refer to the inclusion of exactly one element of a number or list of elements. In general, the term "or" as used herein shall only be interpreted as indicating exclusive alternatives (i.e. "one or the other but not both") when preceded by terms of exclusivity, such as "either," "one of," "only one of," or "exactly one of." "Consisting essentially of," when used in the claims, shall have its ordinary meaning as used in the field of patent law.

[0057] As used herein in the specification and in the claims, the phrase "at least one," in reference to a list of one or more elements, should be understood to mean at least one element selected from any one or more of the elements in the list of elements, but not necessarily including at least one of each and every element specifically listed within the list of elements and not excluding any combinations of elements in the list of elements. This definition also allows that elements may optionally be present other than the elements specifically identified within the list of elements to which the phrase "at least one" refers, whether related or unrelated to those elements specifically identified. Thus, as a non-limiting example, "at least one of A and B" (or, equivalently, "at least one of A or B," or, equivalently "at least one of A and/or B") can refer, in one embodiment, to at least one, optionally including more than one, A, with no B present (and optionally including elements other than B); in another embodiment, to at least one, optionally including more than one, B, with no A present (and optionally including elements other than A); in yet another embodiment, to at least one, optionally including more than one, A, and at least one, optionally including more than one, B (and optionally including other elements); etc.

[0058] It should also be understood that, unless clearly indicated to the contrary, in any methods claimed herein that include more than one step or act, the order of the steps or acts of the method is not necessarily limited to the order in which the steps or acts of the method are recited.

[0059] In the claims, as well as in the specification above, all transitional phrases such as "comprising," "including," "carrying," "having," "containing," "involving," "holding," "composed of," and the like are to be understood to be open-ended, i.e., to mean including but not limited to. Only the transitional phrases "consisting of and "consisting essentially of shall be closed or semi-closed transitional phrases, respectively, as set forth in the United States Patent Office Manual of Patent Examining Procedures, Section 2 111.03.

What is claimed is:

1. A device enabling rapid start-up of a power converter during a start-up period, the power converter controlling power to a solid state lighting load, the device comprising:

a low impedance path formed temporarily between a rectified voltage node and a power converter voltage node for charging the power converter during the start-up period; and

a diode connected between the power converter and an auxiliary winding, the diode comprising a cathode connected to the ground voltage through a first capacitor having a small bypass capacitance and an anode connected to the ground voltage through a second capacitor having a large bulk capacitance, wherein the first capacitor is charged and the second capacitor is not charged while the low impedance path is formed during the start-up period.

2. The device of claim 1, wherein the diode is reverse biased while a voltage at the power converter voltage node is below a steady state value.

3. The device of claim 2, further comprising:

a transistor connected between the rectified voltage node and the power converter voltage node, the low impedance path comprising the transistor when the transistor is turned on during the start-up period; and

a zener diode comprising a cathode connected to the transistor and the rectified voltage node and an anode connected to the ground voltage,

4. The device of claim 3, further comprising:

a first resistor connected between the transistor and the rectified voltage node, the low impedance path further comprising the first resistor when the transistor is turned on during the start-up period; and

a second resistor connected between the cathode of the zener diode and the rectified voltage node, the second resistor enabling enough current to flow through the zener diode to keep the transistor turned off when the power converter is fully charged.

5. The device of claim 2, further comprising:

a first transistor connected between the rectified voltage node and the power converter voltage node, the low impedance path including the first transistor when the first transistor is turned on during the start-up period; and

a second transistor connected between the first transistor and a ground voltage, the second transistor being turned off when the voltage at the power converter voltage node is less than the steady state value, turning on the first transistor during the start-up period.

6. The device of claim 5, wherein the second transistor is turned on when the voltage at the power converter voltage node reaches the steady state value at the end of the start-up period, turning off the first transistor and removing the low impedance path from between the rectified voltage node and the power converter voltage node.

7. A device enabling rapid start-up of a power converter during a start-up period, the power converter controlling power to a solid state lighting load, the device comprising:

a transistor connected between a rectified voltage node and the power converter, the transistor selectively providing a low impedance path from the rectified voltage node to the power converter when the transistor is turned on during the start-up period;

a first diode comprising a cathode connected to the transistor and the rectified voltage node and an anode connected to a ground voltage; and

a second diode connected between an auxiliary winding and the power converter, the second diode comprising a cathode connected to the ground voltage through a first capacitor having a small bypass capacitance and an anode connected to the ground voltage through a second capacitor having a large bulk capacitance, wherein the first capacitor is charged and the second capacitor is not charged while the transistor is turned on at startup.

8. The device of claim 7, wherein the transistor comprises a bipolar junction transistor (BJT) and the first diode comprises a zener diode.

9. The device of claim 8, wherein the transistor is turned on when a voltage at the power converter is less than a steady state voltage of the power converter during the start-up period.

10. The device of claim 8, wherein the low impedance path comprises a first resistor connected in series between the rectified voltage node and a collector of the transistor.

11. The device of claim 10, further comprising a second resistor connected between the rectified voltage node and the cathode of the first diode, enabling enough current to flow through the first diode to keep the base of the transistor below a steady state value of the voltage at the power converter when the power converter is fully charged, keeping the transistor turned off.

12. The device of claim 7, wherein a voltage at the power converter is less than a steady state voltage of the power converter during the start-up period.

13. A device enabling rapid start-up of a power converter during a start-up period, the power converter controlling power to a solid state lighting load, the device comprising:

a first transistor connected between a rectified voltage node and a power converter node, which provides a voltage powering the power converter, the first transistor selectively providing a low impedance path from the rectified voltage node to the power converter node when the first transistor is turned on during the start-up period;

a second transistor connected between the first transistor and a ground voltage; and

a diode connected between an auxiliary winding and the power converter node, the diode comprising a cathode connected to the ground voltage through a first capacitor having a small bypass capacitance and an anode connected to the ground voltage through a second capacitor having a large bulk capacitance,

wherein the second transistor is turned off when the voltage at the power converter node is less than a steady state value during the start-up period, turning on the first transistor to provide the low impedance path, and charging the first capacitor, but not the second capacitor, and

wherein the second transistor is turned on when the voltage at the power converter node reaches the steady state value at the end of the start-up period, turning off the first transistor to remove the low impedance path, and charging the first capacitor and the second capacitor.

14. The device of claim 14, wherein the first transistor comprises a field-effect transistor (FET) and the second transistor comprises a bipolar junction transistor (BJT).

15. The device of claim 15, wherein a gate of the first transistor is connected to a source of the first transistor when the second transistor is turned off, and a drain of the first transistor is connected to the rectified voltage node through a first resistor and the gate of the first transistor is connected to the source of the first transistor through a second resistor.

16. The device of claim 15, wherein the second transistor comprises a base connected to the power converter node, a collector connected to the gate of the first transistor and an emitter connected to the ground voltage.

17. The device of claim 16, wherein the collector is connected to the gate of the first transistor through a third resistor and the base is connected to the power converter node through a fourth resistor and to the ground voltage through a fifth resistor.

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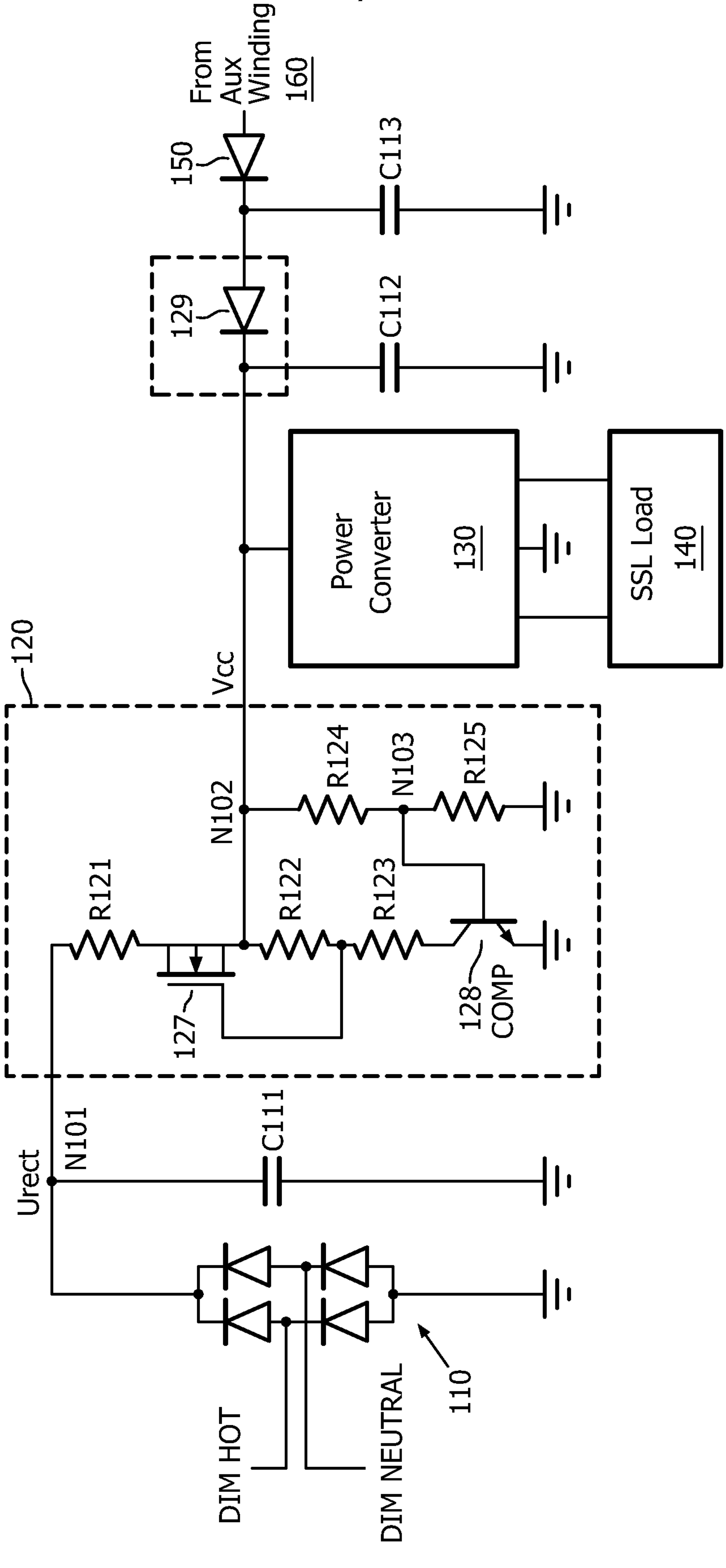
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FIG. 1

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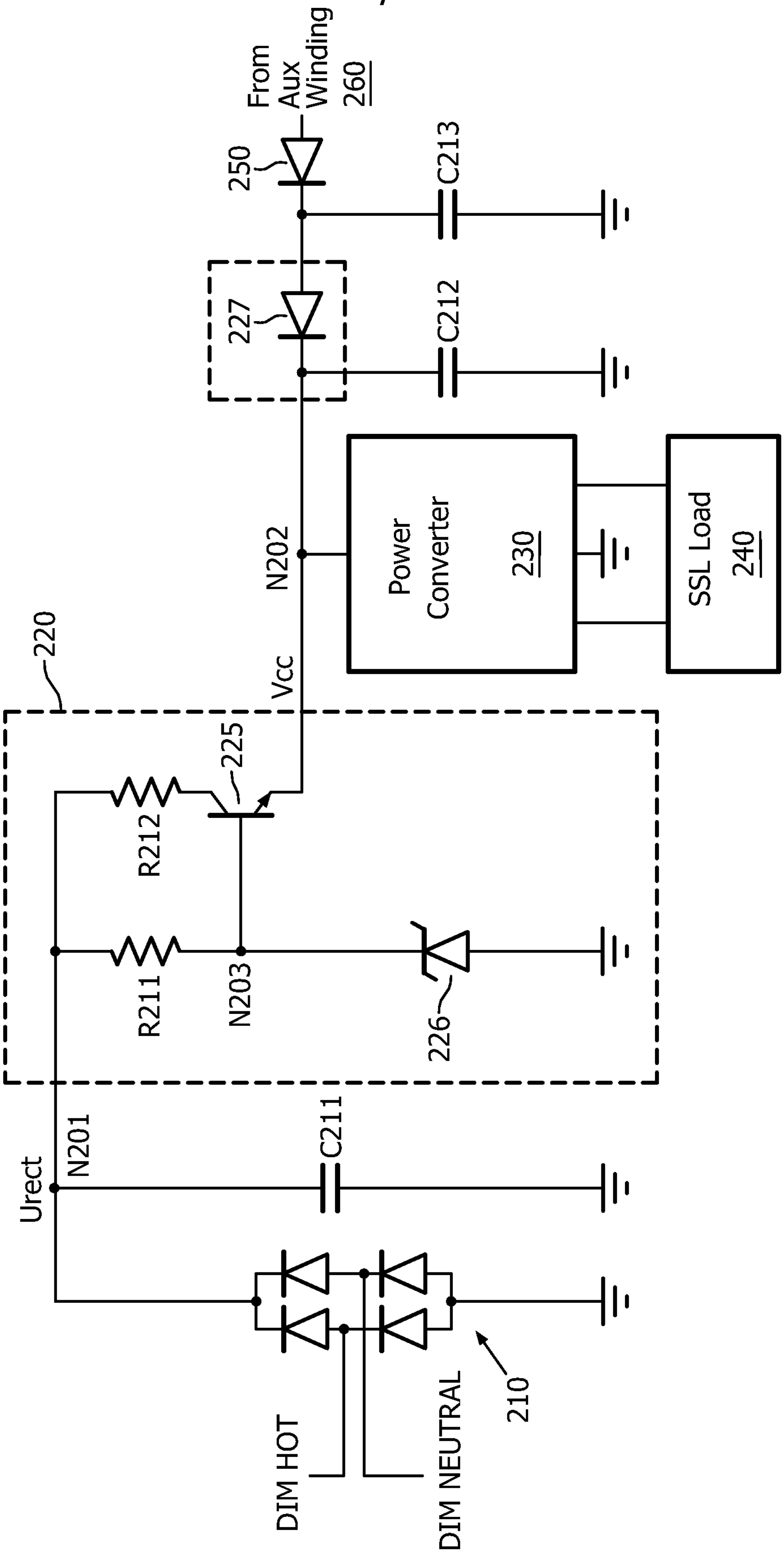
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Winding
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R212
R211
N203
226
Urect
N201
C211
DIM HOT
DIM NEUTRAL
210

FIG. 2

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2010/054072

A. CLASSIFICATION OF SUBJECT MATTER
INV. H02M1/36
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H02M H05B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal , IBM-TDB

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 815 383 A (LEI JIMES [US]) 29 September 1998 (1998-09-29) the whole document	1-17
X	US 5 880 942 A (LEU FANG-JYE [TW]) 9 March 1999 (1999-03-09) the whole document	1-17
A	"LOW LOSS-TYPE STARTER CIRCUIT FOR SWITCHING MODE POWER SUPPLY", IBM TECHNICAL DISCLOSURE BULLETIN, INTERNATIONAL BUSINESS MACHINES CORP. (THORNWOOD), US, vol. 31, no. 5, 1 October 1988 (1988-10-01), page 424/425, XP000023170, ISSN: 0018-8689 the whole document	1-4,7-12

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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier document but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
22 February 2011	01/03/2011

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Gardella, Simone

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2010/054072

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP 0 585 788 A1 (POWER INTEGRATIONS INC [US]) 9 March 1994 (1994-03-09) column 1, line 57 - column 2, line 27 figure 2 -----	1,2,5,6, 13-17
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