Abstract: A system for controlling an electrical circuit, subject to a loss of power event, includes a microprocessor, timing capacitor and discharge resistor. The microprocessor controls operation of the electrical circuit according to a dimming profile. The timing capacitor is connected to an input/output pin of the microprocessor, and charges to a predetermined voltage via the input/output pin when uninterrupted power is applied to the microprocessor before the loss of power event, and discharges at a fixed discharge rate to a discharge voltage during the loss of power event. The timing capacitor discharges through the parallel connected discharge resistor during the loss of power event. The microprocessor measures the discharge voltage of the timing capacitor via the input/output pin, and determines that the loss of power event was a temporary power interruption when the measured discharge voltage is above a predetermined threshold, enabling continued operation according to the dimming profile.
CONTROLLING LIGHTING SYSTEM SUBJECTED TO LOSS OF POWER EVENT

Technical Field

[0001] Embodiments of the present invention are directed to a system and a method for determining whether a loss of power event incurred by a lighting system is a temporary power interruption or an extended power outage.

Background

[0002] Digital lighting technologies, i.e., illumination based on semiconductor light sources, such as light-emitting diodes (LEDs), offer a viable alternative to traditional fluorescent, 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 different colors, e.g., red, green, and blue, as well as a 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 and 6,211,626, which are hereby incorporated by reference.

[0003] Many lighting systems use dimmers to control the amount of light produced by the light sources controlled by the lighting systems. The dimmers may be implemented according to a variety of dimming schemes, such as digital addressable lighting interface (DALI) dimming, 1-IOV dimming, and/or mains dimming. Adoption of different dimming schemes may be determined by a number of factors, such as user preference, availability and environment. In a typical lighting application, an electronic driver receives control signals, including dimming inputs, from a controller employing various dimming schemes. In response to the dimming inputs, the electronic driver provides operating currents and voltages to the light source to achieve the dimming levels corresponding to the dimming inputs.
[0004] As energy saving requirements become more stringent, the need for intelligent lighting systems increases. For example, some lighting applications operate light sources in accordance with dimming profiles, which consist of lighting levels associated with a sequence of events that occur according to a predetermined time schedule. The events may include varying brightness of the light sources (e.g., by adjusting dimming levels for a portion of an on-cycle) based on predetermined calculations, events, passage of time, and/or user-defined profiles. An illustrative implementation of a dimming profile is outdoor lighting in a public area, which may be programmed to provide progressively less light during periods of anticipated low traffic conditions and more light during period of anticipated high traffic conditions, enabling significant power savings. Similarly, a dimming profile may be tied to natural lighting patterns, such as dawn, midday, dusk, nighttime, etc. Dynadimmer and Chronosense, both of which are available from Koninklijke Philips N.V. (hereinafter "Philips"), are examples of (0-10V) lighting system products that control dimming operations of light sources according to predetermined dimming profiles.

[0005] However, dimming profiles are particularly sensitive to situations in which the lighting system loses power. For example, power lines may experience power drop-outs or outages referred to as "loss of power events," adversely affecting power quality and causing critical electrical components of the lighting system to shut down. A loss of power event may be a "temporary power interruption" (or power glitch) in the power supply, e.g., caused by voltage sags or spikes, depriving the lighting system of power for a relatively short period of time (e.g., a few milliseconds to tens of seconds). In contrast, a loss of power event may be an "extended power outage," e.g., caused by downed power lines, damaged transformers, or intentional shut-down of the power grid, depriving the lighting system of power for a relatively long period of time (e.g., on order of minutes or hours). Such power quality problems are especially common in emerging markets, such as China and India, where the power infrastructure is under development.

[0006] A typical lighting system is capable of withstanding short duration power interruptions, since it has some form of charge-storage, e.g., in the form of bulk capacitors or battery back-ups. However, the charge-storage often provides power for a short period of time
(e.g., tens of milliseconds), and thus any extended power outages will reset the complete circuit of the lighting system. Such a reset will cause the lighting system to restart from an initial setting, and thus prevent the dimming profile from operating on the designed schedule and otherwise delivering the anticipated power savings. In fact, in regions where the power quality is low, it is possible that light output by a light source may never dim in accordance with a dimming profile if the electronic power supply frequently restarts due to loss of power events.

[0007] Thus, it is desirable to provide a lighting system that determines whether a loss of power event is sufficiently short to enable a dimming profile to continue uninterrupted (as if the power were never interrupted), thereby preventing the dimming profile from being needlessly restarted for minor power glitches. Also, it is desirable to provide a lighting system that determines the actual duration of the loss of power event when it is sufficiently short to enable the dimming profile to continue uninterrupted, so that appropriate adjustments to the dimming profile may be made.

Summary

[0008] The present disclosure is directed to inventive systems and methods for determining whether a loss of power event incurred by a lighting system is a temporary power interruption or an extended power outage.

[0009] Generally, in one aspect, a system for controlling an electrical circuit, subject to a loss of power event, includes a microprocessor, a timing capacitor and a discharge resistor. The microprocessor is configured to control operation of the electrical circuit according to a dimming profile, the microprocessor having multiple input/output pins. The timing capacitor is connected to one input/output pin of the multiple input/output pins of the microprocessor. The timing capacitor charges to a predetermined voltage via the one input/output pin when uninterrupted power is applied to the microprocessor before the loss of power event, and discharges at a fixed discharge rate from the predetermined voltage to a discharge voltage during the loss of power event. The discharge resistor is connected in parallel with the timing capacitor through which the timing capacitor discharges during the loss of power event. The microprocessor is configured to measure the discharge voltage of the timing capacitor via the
one input/output pin, and to determine that the loss of power event was a temporary power interruption when the measured discharge voltage of the timing capacitor is above a predetermined threshold, enabling continued operation of the electrical circuit according to the dimming profile.

[0010] In another aspect, a method is provided for operating a microprocessor configured to control an electrical circuit according to a dimming profile, a timing capacitor being connected in parallel with a discharge resistor between an input/output pin of the microprocessor and ground voltage. The method includes configuring the input/output pin of the microprocessor as an analog input at power-up of the microprocessor after being shut-down, and measuring a voltage across the timing capacitor at the input/output pin. When the measured voltage is greater than a predetermined threshold voltage, it is determined that the microprocessor is returning from a temporary power interruption and continues to control the electrical circuit according to the dimming profile as before the microprocessor was shut-down. The timing capacitor discharges at a fixed discharge rate while the microprocessor is power shut-down.

[0011] In another aspect, a method is provided for characterizing a loss of power event, incurred by an electrical circuit controlled by a microprocessor according to a predetermined dimming profile, using a timing capacitor connected to a microprocessor pin of the microprocessor. The method includes charging the timing capacitor to a predetermined voltage during a normal operating mode when uninterrupted power is applied to the microprocessor before the loss of power event; sampling a voltage of the timing capacitor at the microprocessor pin when powering-up after the loss of power event, where the timing capacitor discharges at a fixed discharge rate through a parallel connected discharge resistor during the loss of power event; determining whether the loss of power event was a temporary power interruption based on the sampled voltage; and continuing operation of the electrical circuit according to the predetermined dimming profile when the loss of power event is determined to have been the temporary power interruption. Charging the timing capacitor is performed using the microprocessor pin configured as an output pin, and sampling the voltage of the timing capacitor is performed using the microprocessor pin configured as an input pin.
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.

For example, one implementation of an LED configured to generate essentially white light (e.g., a white LED) 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, a white light LED 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.

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 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.

[0015] 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 saturation, galvano-luminescent sources, crystallo-luminescent sources, kine-luminescent sources, thermo-luminescent sources, triboluminescent sources, sonoluminescent sources, radioluminescent sources, and luminescent polymers.

[0016] A "lighting driver" or "electronic driver" is used herein to refer to an apparatus that supplies electrical power to one or more light sources in a format to enable the light sources to emit a pre-determined controlled amount of light. In particular, a lighting driver may receive electrical power in a first format (e.g., AC mains power; a fixed DC voltage; etc.) and supplies power in a second format that is tailored to the requirements of the light source(s) (e.g., LED light source(s)) that it drives.

[0017] The term "lighting module" is used herein to refer to a module, which may include a circuit board (e.g., a printed circuit board) having one or more light sources mounted thereon, as well as one or more associated electronic components, such as sensors, current sources, etc., and which is configured to be connected to a lighting driver. Such lighting modules may be plugged into slots in a lighting fixture, or a motherboard, on which the lighting driver may be provided. The term "LED module" is used herein to refer to a module, which may include a circuit board (e.g., a printed circuit board) having one or more LEDs mounted thereon, as well as one or more associated electronic components, such as sensors, current sources, etc., and which is configured to be connected to a lighting driver. Such lighting modules may be plugged
into slots in a lighting fixture, or a motherboard, on which the lighting driver may be provided.

[0018] The terms "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; a lighting driver) 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.

[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 will be understood that when an element is referred to as being "connected" or "coupled" to another element, it can be directly connected or coupled to the other element or intervening elements may be present. In contrast, when an element is referred to as being "directly connected" or "directly coupled" to another element, there are no intervening elements present.
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

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

FIG. 1 is a block diagram of a lighting system, according to a representative embodiment.

FIG. 2 is a block diagram of an electronic controller in the lighting system of FIG. 1, according to a representative embodiment.

FIG. 3A is a circuit diagram of an interruption timing circuit of the electronic controller of FIG. 2, according to a representative embodiment.

FIG. 3B is a circuit diagram of an interruption timing circuit of the electronic controller of FIG. 2, according to a representative embodiment.

FIG. 4 is a flow diagram of a method for controlling a lighting system subjected to loss of power events, according to a representative embodiment.

Detailed Description

As discussed above, there is a need for defining loss of power events, and enabling lighting systems to continue to operating according to dimming profiles when the loss of power events are sustainable.
Therefore, Applicant has recognized and appreciated that it would be beneficial to provide a system and method for determining whether a loss of power event incurred by a lighting system is a temporary power interruption or an extended power outage. The Applicant has further recognized that it would be beneficial to provide a system and method of determining the amount of time the lighting system is shut down pursuant to a temporary power interruption in order to appropriately adjust a dimming profile for adjusting brightness (or dimming levels) of light sources controlled by the lighting system.

In view of the foregoing, various embodiments and implementations of the present invention are directed to a system and method to account for lost time during a loss of power event which is long enough that an internal control circuit of a lighting system, such as a microprocessor circuit, loses its power supply (i.e., is shut-down), and thus is not able to count time. As mentioned above, conventional systems account for lost power in a variety of ways. For example, a conventional power supply may have a large electrolytic storage capacitor or a rechargeable battery back-up to provide power to the lighting system during a loss of power event. The storage capacitor may provide the microprocessor of the lighting system enough time to "ride out" a relative short loss of power event, such as a mains interruption, without losing power, while the battery back-up will activate and provide power for a somewhat longer period of time. However, the storage capacitor is typically quite bulky, especially if the microprocessor consumes a large amount of current, since the amount of energy storage required is directly proportional to the size and cost of the storage capacitor. Also, the storage capacitor typically has a very large variation in capacitance ranging over temperature, and generally loses capacitance over its lifetime. As a result, its storage capacity not only diminishes, but also the capacitor would have to be over-designed to anticipate worst-case conditions of operation to ensure a reliable source of power during the mains interruption. Likewise, the battery back-up is relatively expensive, and therefore is typically not sufficiently cost effective for applications such as lighting systems.

Other conventional lighting systems use a circuit to charge a small capacitor by means of one or more microprocessor pins configured as output pins when the circuit is powered, and allow the small capacitor to discharge at a predetermined rate during a loss of
power event. The voltage across the capacitor is then sampled by a different microprocessor pin configured as an input pin. For example, such circuits are included in the Dynadimmer and Chronosense products available from Philips. The circuits include a microprocessor that samples the voltage across multiple capacitors using the signal (and corresponding microprocessor pin) PDCJN, that controls charging of the multiple capacitor using the signal (and corresponding microprocessor pin) PDC_CHARGE, and that disengages the charging circuit using the signal (and corresponding microprocessor pin) PDC_CON. The problem with this scheme is that it uses a number of different circuit elements, components and three different pins from the microprocessor, which equates to complexity and cost.

[0032] Generally, according to embodiments of the invention, a timing capacitor is charged to a known voltage via an input/output pin of a microprocessor during normal running mode of the lighting system (during which the microprocessor receives an uninterrupted power supply). After a loss of power event occurs, during which the timing capacitor discharges at a predetermined rate, the microprocessor recovers by determining the voltage across the timing capacitor at the same input/output pin, to determine whether the loss of power event was a sustainable temporary power interruption or an extended power outage. A temporary power interruption is a relatively short period of time, which may be defined by a user and/or designer, that has been identified as the maximum amount of time the lighting system is able to shut down without adversely affecting implementation the dimming profile, e.g., including self-learning. For example, a temporary power interruption may be a period of time in milliseconds or seconds (e.g., about 1 millisecond to about 60 seconds). An extended power outage is a relatively long period of time (e.g., on order of minutes or hours), which is complementary to the temporary power interruption and thus is an amount of time from which the dimming profile of the lighting system is deemed to be unable to recover, as a practical matter. An extended power outage may therefore require restarting the dimming profile. Of course, the ranges of what is considered a temporary power interruption and an extended power outage may be varied, for example, through selection of the size of the timing capacitor, as discussed below, without departing from the scope of the present teachings.
[0033] When the loss of power event is determined to be a temporary power interruption, the microprocessor continues to execute control of the light source, e.g., in accordance with a dimming profile, as if the temporary power interruption had not occurred. In an embodiment, the microprocessor may also determine the time duration of the temporary power interruption, and compensate for that time duration with respect to the dimming profile. When the loss of power event is determined to be an extended power outage, the microprocessor takes steps to reset its control of the light source, which may include reinitiating the dimming profile.

[0034] Accordingly, characterization of the loss of power event requires only one microprocessor pin, one capacitor and one resistor. The microprocessor pin is configured as an input pin at each start-up (e.g., following a loss of power event) to measure voltage across the capacitor. Subsequently, the same microprocessor pin is re-configured as an output pin to recharge the capacitor in preparation for the next loss of power event. This ties up fewer microprocessor pins, and requires no other components to be engaged or disengaged during different modes of operation.

[0035] FIG. 1 is a block diagram of a lighting system, according to a representative embodiment.

[0036] Referring to FIG. 1, lighting system 100 includes an electronic driver (e.g., LED driver) 110, a light source 120, a network 130 and a user interface 140. The lighting system 100 may be used in indoor and/or outdoor lighting installations, and is generally designed to control the amount of light provided by the light source 110. For example, the lighting system 100 may manage on and off times, as well as brightness (dimming levels), of the light source 120. These operations may be performed in accordance with one or more dimming profiles, which may incorporate various factors or inputs, such as time of day, time from initial start-up of the lighting system 100, presence or absence of daylight or other light source, or the like.

[0037] The electronic driver 110 controls the amount of current and voltage applied to the light source 120. Accordingly, the electronic driver 110 is able to turn the light source 120 on or off, and to selectively apply various dimming levels. The electronic driver 110 may be
configured to implement various dimming schemes, such as 1-LOV, DALI, mains dimming, and/or Dynadimmer dimming, for example, as well as fixed dimming profiles. For purposes of illustration, it may be assumed that a dimming profile implemented by the electronic driver 110 adjusts dimming levels of the light source 120 according to predetermined time periods that may be tracked from an initial start-up time of the electronic driver 110, as mentioned above. For example, a simple dimming profile may include dimming the light source 120 to 50 percent light output and then returning to 100 percent light output every 12 hours. The electronic driver 110 includes a solid state chip incorporating a microprocessor (e.g., illustrative microprocessor 220, discussed below) configured to execute control of the light source 120 in accordance with dimming profiles.

[0038] In general, the electronic driver 110 receives control signals for the different dimming schemes and/or dimming profiles, a power signal for driving the light source 120, and user inputs used to program, configure, or otherwise manage operations of the electronic driver 110. The electronic driver 110 may control the current and voltage supplied to the light source 120 according to the selected dimming scheme and/or dimming profile and related control signals, e.g., by manipulating the power signal.

[0039] The light source 120 generates light according to the currents and voltages provided from the electronic driver 110. The light source 120 may include one or more LEDs or other solid state light sources in which brightness (dimming level) may be adjusted according to the different dimming schemes and dimming profiles to provide different levels of light in different contexts. For example, the brightness may be adjusted according to the dimming profile, detected environmental factors and/or specific user inputs. The light source 120 may also be based on other lighting technologies, such as E-Fluo or E-HID, for example, with a matching electronic driver/ballast 110 for that particular lighting technology.

[0040] The user interface 140 enables a user to submit information to control operations of the electronic driver 110. The user interface 140 may be implemented, for example, by a personal computer (PC) application. In the example depicted in FIG. 1, the user interface 140 communicates with the electronic driver 110 through a network 130, which may be any type of wired or wireless network, such as the Internet or other packet switching network. However,
the user interface 140 may communicate through various alternative means, such as a remote control or direct connection to the electronic driver 110, without departing from the scope of the present teachings, as would be apparent to one of ordinary skill in the art. The user interface 140 may be used to configure, override or reinitiate one or more dimming profiles, for example, and to submit queries to and receive responses from the electronic driver 110.

[0041] FIG. 2 is a block diagram of an electronic driver of a lighting system, according to a representative embodiment. The electronic driver may be used as the electronic driver 110 shown in FIG. 1.

[0042] Referring to FIG. 2, the electronic driver 210 includes dimming detection circuit 225 and power converter 240, which receives power control signal 229 from the dimming detection circuit 225 to control the dimming level to be applied to the light source 120. The dimming detection circuit 225 and the power converter 240 receive rectified voltage, e.g., from voltage mains, via a dimmer circuit (not shown) and a rectification circuit (not shown), as would be apparent to one of ordinary skill in the art.

[0043] In the depicted embodiment, the dimming detection circuit 225 includes dimming interface 215, microprocessor 220, interruption timing circuit 228, and interruption timing circuit 230. The dimming interface 215 indicates the desired dimming level to be applied to the light source 120, typically in response to the level of the received rectified voltage, according to the type of interface. For example, a 1-10V dimming interface receives an analog input voltage that ranges from 1V to 10V, and provides a corresponding input to the microcontroller 220. The magnitude of the input voltage determines the amount of dimming implemented by the power converter 240 under control of the microprocessor 220 via the power control signal 229. In particular, lowering the magnitude of the input voltage increases the amount of dimming and vice versa. A DALI dimming interface receives digital signals that define the amount of dimming to be implemented by the power converter 240 under control of the microprocessor 220. For example, a mains dimming interface receives the rectified mains voltage and provides an input to the microprocessor 220 accordingly. Mains dimming may be performed, for example, by reducing the amplitude of the received mains voltage according to the desired level of dimming, and appropriate power control signal 229 is applied to the power converter 240.
under control of the microprocessor 220 to control the dimming of the light source 120 through an output driver.

[0044] The microprocessor 220 controls an electrical circuit, comprising at least the power converter 240 and the light source 120, according to the input signals. Functionality of the microprocessor 220 may be implemented by hardware, software, firmware, or any combination thereof. The dimming commands indicate the amount of current and voltage to be applied by the power converter 240 to the light source 120 via the power control signal 229. The microcontroller 220 is also able to communicate with an external device, such as the user interface 140, through a corresponding input/output (I/O) interface. This communication may be used to select a dimming scheme and/or dimming profile, for example, and to output status information regarding the electronic driver 210 and the light source 120.

[0045] In the depicted embodiment, the microprocessor 220 includes a dimming selector 222 and an integrated Dynadimmer module 224. For example, the dimming selector 222 may be a sub-routine or a section of software code internal to the microcontroller 220 which determines what the dimming level should be based on the available information. The dimming selector selects the dimming scheme of the dimming interface 215 or the integrated Dynadimmer module 224. This selection may be made, for example, in response to user inputs or detected environmental conditions, such as natural light or motion. The integrated Dynadimmer module 224 implements a dimming scheme by which the light source 120 is dimmed to light levels according to a predetermined dimming profile using information derived from on-time duration of the electronic driver 210 (or the microprocessor 220). The power converter 240 receives the power control signal 229, including the dimming commands, from the microprocessor 220, and provides currents and voltages to the light source 120 accordingly through the output driver.

[0046] Notably, an algorithm implemented by Dynadimmer module 224 may be self-learning, in that it adjusts to changing durations of night and/or day cycles over the course of a year, and adjusts lighting according to a dimming profile to eventually obtain optimal power savings. In order to establish a "valid" estimate of the night cycle, for example, the Dynadimmer module 224 needs to have consistent timing information for the first three
consecutive days (during which there is no dimming). It then uses the preceding three days to adjust the dimming profile as needed once the Dynadimmer module 224 notices a "valid" change in timing. In comparison, an "invalid" change in timing is any cycle that is shorter than two hours, which is automatically ignored as a "glitch." Therefore, if the power quality is generally poor with frequent loss of power events, then the Dynadimmer module 224 is not able to "learn" the appropriate cycles due to frequent interruptions causing an "invalid" night cycle estimation. For example, if there are loss of power events due to poor power quality within the first three days, then establishing the optimal dimming profile may become impossible since the Dynadimmer module 224 does not receive any "valid" timing information. The Dynadimmer module 224 thus continues to remain in the "learning" mode and never executes a dimming profile. Consequently, the customer will not get the anticipated power savings.

**[0047]** The power interruption detection circuit 228 is configured to receive the rectified voltage and to inform the microprocessor 220 when a loss of power event occurs. This enables the microprocessor 220 to start saving data necessary to maintain the dimming profile before the supply voltage Vcc of the microprocessor 220 (e.g., 3.3 volts) goes low as a result of the loss of power event. Generally there are a few tens of milliseconds between the input power being interrupted by the loss of power event and the supply voltage Vcc of the microprocessor 220 going low.

**[0048]** The interruption timing circuit 230 is configured to inform the microprocessor 220 whether a loss of power event should be considered a relatively short temporary power interruption or a relatively long extended power outage. When the interruption timing circuit 230 indicates a temporary power interruption, the microprocessor 220 continues operation of the light source 120 under control of the power converter 240 according to the dimming profile essentially from the point of occurrence of the temporary power interruption. For example, in an embodiment, the time of a last valid ON cycle of the microprocessor 220 (and/or the dimming detection circuit 225) before the temporary power interruption is saved in order to determine the relative time in the dimming profile where the microprocessor 220 should be once power is restored. Therefore, following the temporary power interruption, the
microprocessor 220 is able to continue to follow the dimming profile correctly despite the occurrence of the temporary power interruption and/or the respective lengths of back-to-back valid ON cycles. Also, in certain embodiments, the interruption timing circuit 230 enables the microprocessor 220 to calculate how long the power has been off (lost time) during a temporary power interruption, as discussed below. When the interruption timing circuit 230 indicates an extended power outage, the microprocessor 220 restarts the dimming profile.

[0049] FIGs. 3A and 3B are circuit diagrams of interruption timing circuits of an electronic driver of a lighting system, according to representative alternative embodiments. The interruption timing circuits may be used as the interruption timing circuit 230 shown in FIG. 2.

[0050] Referring to FIG. 3A, interruption timing circuit 230A includes timing capacitor 231 and discharge resistor 232 connected in parallel with the timing capacitor 231. More particularly, the timing capacitor 232 and the discharge resistor 232 are connected in parallel between input/output pin 221 of the microprocessor 220 and ground voltage. The input/output pin 221 is one of multiple microprocessor pins of the microprocessor 220.

[0051] In the normal running mode, the electronic driver 210, and more particularly the microprocessor 220, receives an uninterrupted supply of power. Therefore, the microprocessor 220 configures the input/output pin 221 as an analog output, and charges the timing capacitor 231 to the supply voltage Vcc of the microprocessor 220 (e.g., 3.3 volts), in preparation for shut-down of the microprocessor 220 during a subsequent loss of power event. That is, the timing capacitor 231 is charged so that the capacitor voltage is substantially equal to the supply voltage Vcc. The input/output pin 221 of the microprocessor 220 is set to high, thus providing "pull-up" to the supply voltage Vcc to enable the charging of the timing capacitor 231.

[0052] The timing capacitor 231 will remain fully charged until there is a loss of power event, which stops the supply of power to the microprocessor 220, causing it to shut-down. The loss of power event may be a temporary power interruption (or power glitch) in the power supply, e.g., caused by voltage sags or spikes, which may deprive the microprocessor 220 of power for a relatively short period of time (e.g., less than about 10 seconds). In contrast, the loss of power event may be an extended power outage, e.g., caused by downed power lines, damaged
transformers, or intentional management of the power grid, which may deprive the microprocessor 220 of power for a relatively long period of time (e.g., greater than about 10 seconds, lasting minutes or even hours). The actual threshold between a temporary power interruption and an extended power outage may be adjustable, e.g., by the user via the user interface 140, depending on the specific requirements and capabilities of the lighting system 100.

[0053] At the time of the loss of power event, the timing capacitor 231 begins discharging through the discharge resistor 232 at a fixed discharge rate. For example, the time constant of the discharge is given by the product of the capacitance value \( C_I \) of the timing capacitor 231 and the resistance value \( R_D \) of the discharge resistor 232 (i.e., \( C_I \times R_D \) seconds). In an embodiment, the timing capacitor 231 will completely discharge to nearly zero volts in about five time constants (i.e., \( 5 \times C_I \times R_D \) seconds). Therefore, the capacitance value \( C_I \) of the timing capacitor 231 and the resistance value \( R_D \) of the discharge resistor 232 are chosen to provide an appropriate amount of time corresponding to a temporary power interruption for a particular system. The length of time of an acceptable temporary power interruption (implemented as a practical matter by the values of the timing capacitor 231 and the discharge resistor 232) depends upon particular design specifications and system requirements, as would be apparent to one of ordinary skill in the art.

[0054] Accordingly, a temporary power interruption of up to a several seconds may be sustained, and the microprocessor 220 is able to retain the last operating point before occurrence of the loss of power event. If the loss of power event lasts longer than the time period of an acceptable temporary power interruption, then the loss of power event is considered to be an extended power outage, in which case the microprocessor 220 will have to restart the dimming profile. For example, the extended power outage may be treated as the start of a new cycle or a next night. Utilization of the interruption timing circuit 230A is based on the assumption that most loss of power events in the field are temporary power interruptions, such as line fluctuations following a distribution, lasting less than two or three seconds. Therefore, for the relatively few instances in which a loss of power event results in a prolonged absence of power (extended power outage), it is acceptable to restart the dimming
profile being implemented by the microprocessor 220, which is a more complex endeavor that possibly requires user input (such as re-entering time of day and corresponding dimming settings) to initiate properly. However, there is no limitation on the length of time the lighting system 100 may be allowed to go without power before requiring restarting of the dimming profile, since increasing the capacitance value \( C_T \) and/or the resistance value \( R_D \) of the interruption timing circuit 230 allows the microprocessor 220 to sustain longer power interruptions. Of course, the longer power interruptions that are sustained may result in unacceptable disruption of the dimming profile in a shorter period of time. In some embodiments, the microprocessor 220 will also disregard any ON cycles shorter than four hours as a "glitch," and thus will not record those ON cycles.

[0055] In an embodiment, the microprocessor 220 may calculate the specific amount of time that elapses during a temporary power interruption ("lost time") based on the remaining amount of voltage across the timing capacitor 231 when power is regained. Accordingly, in addition to continuing with the dimming profile that was in place prior to the temporary power interruption, the microprocessor 220 is able to add the lost time back into the original timing sequence. This enables the electronic driver 210 to have corrected timing computations, and hence more accurate implementation of the dimming profile (since aggregated lost time incurred pursuant to several temporary power interruptions may become disruptive).

[0056] Also, in an embodiment, the Dynadimmer module 224 is attempting to learn and adjust the night cycle, for example, as discussed above. For example, there may be a temporary power interruption after 4.5 hours in normal running mode (On cycle), which is long enough to reset the internal power supply of the microprocessor 220, and this may be followed by a 3.5 hour ON cycle before the next morning. Without the electronic driver 210, this situation would be treated as two distinct night cycles, one lasting 4.5 hours and another lasting 3.5 hours. That is, the circuit would assume that the night duration was 4.5 hours, and ignore the subsequent 3.5 hour ON cycle since it is shorter than 4 hours. However, using the information provided by the interruption timing circuit 230, the microprocessor 220 is aware when a loss of power event is short (i.e., a temporary power interruption), and will therefore add the 3.5 hours to the preceding 4.5 hours to accurately determine that the night cycle was
actually 8 hours. Otherwise, the Dynadimmer logic would effectively mal-function by wrongly estimating the night cycle. For this to work, the microprocessor 220 saves the duration of the last ON cycle before a temporary power interruption occurs. In an embodiment, the microprocessor 220 may also add in the lost time calculated based on the remaining amount of voltage across the timing capacitor 231 when power is regained, as discussed above.

[0057] Referring to FIG. 3B, interruption timing circuit 230B includes timing capacitor 231 and discharge resistor 232 connected in parallel with the timing capacitor 231, and additional charge resistor 233 connected between input/output pin 221 of the microprocessor 220 and node 234. More particularly, the timing capacitor 231 and the discharge resistor 232 are connected in parallel between the node 234 and ground voltage. The charge resistor 233 is configured to limit the amount of current flowing out of the timing capacitor 231 into the input/output pin 221 when the timing capacitor 231 is discharging (i.e., during a loss of power event).

[0058] For the configuration shown in FIG. 3B, it is assumed that the input/output pin 221 of the microprocessor 220 (as well as other microprocessor pins of the microprocessor 220) has a protection diode (not shown) going to the supply voltage Vcc. Therefore, when the supply voltage Vcc drops, the protection diode pulls the charge back out of the microprocessor 220, rendering the functionality of the interruption timing circuit 230A ineffective, as a practical matter. By including the charge resistor 233, the amount of current that can flow out of the timing capacitor 231 into the input/output pin 221 during a loss of power event is essentially limited. If the resistance value (Rc) of the charge resistor 233 is much larger than the resistance value (Rd) of the discharge resistor 232, then error potentially caused by protection diode current is reduced to a negligible amount in overall determination of the elapsed time based on the capacitor voltage. The resistance value of the charge resistor 233 may be limited, though, by input bias current of the input/output pin 221 when it is configured as an input pin at power-up. The input bias current causes error proportional to the product of the input bias current and the resistance value of the charge resistor 233. Thus, the resistance value of the charge resistor 233 must be small enough to keep the error due to the input bias current within acceptable limits.
Notably, in the normal running mode, when the input/output pin 221 is configured as an output pin set to high, the large resistance value of the charge resistor 233 slows the charging of the timing capacitor 231. This is typically acceptable since the time of the normal running mode is generally much longer than the loss of power events. However, a problem may arise if the next loss of power event occurs before the timing capacitor 231 has time to fully recharge. Therefore, to prevent slowing of the charging process, a bypass diode (not shown) may be added across the charge resistor 233 with forward flow pointing into the timing capacitor 231, so that the charge resistor 233 need not be considered in calculations for charging time, but only in calculations for discharging time.

Thus, the elapsed time indicated by the voltage across the timing capacitor 231 can be used as a simple indication of whether a loss of power event was a temporary power interruption or an extended power outage. The actual length of the elapsed time may also be calculated and used in computations as part of a Dynadimmer algorithm, for example, for adjusting a time profile.

FIG. 4 is a flow diagram of operating an electronic driver of a lighting system to account for a loss of power event, according to representative alternative. Initially, the capacitance value \( C_r \) and/or the resistance value \( R_r \) of the interruption timing circuit 230A, 230B are selected (in design and/or set-up stages) based on specification for how long of a temporary power interruption should be sustained before requiring the dimming profile implemented by the microprocessor 220 to be restarted. For example, these values may be predetermined during design, or the timing capacitor 231 may be a variable capacitor and/or the discharge resistor 232 may be a variable resistor, enabling easy operational adjustment to the length of the acceptable temporary power interruption.

Referring to FIG. 4, in block S411, a loss of power event is experienced during normal operation of an electronic driver (e.g., electronic driver 110), including a microprocessor circuit (e.g., microprocessor 220), for driving a solid state lighting circuit (e.g., light source 120). Upon occurrence of the loss of power event, current operation parameters of the electronic driver, including the time of the immediately preceding ON-cycle, is saved into non-volatile memory (not shown) in block S412. The current operation parameters may be set-point values, and
saving the set-point values may be handled by circuitry that stores enough energy to give the microprocessor 220 a few tens of milliseconds (e.g., about 10 to about 50 milliseconds) to save its data, as would be apparent to one of ordinary skill in the art.

[0063] In block S413, the input/output pin 221 of the microprocessor 220 is configured as an analog input in response to a subsequent power-up event, following the loss of power event in block S411. The voltage at the input/output pin 221 is then measured in block S414. This measured voltage corresponds to the voltage across the timing capacitor 231, which has been discharging from a fixed voltage (e.g., the supply voltage Vcc of the microprocessor 220) through the discharge resistor 232 at a fixed discharge rate. The discharging of the timing capacitor 231 occurs during the loss of power event (causing the microprocessor 220 to shutdown) immediately preceding the power-up event mentioned in block S413.

[0064] In block S415, it is determined whether the measured capacitor voltage is greater than a pre-determined threshold. When the measured capacitor voltage is greater than the pre-determined threshold (block S415: Yes), the microprocessor 220 determines (by inference) in block S416 that it is returning from a temporary power interruption, as discussed above, and therefore continues implementing the dimming profile at block S417 as before the occurrence of the loss of power event. In addition, the time of the immediately preceding ON cycle that was saved in block S412 may be added to the current ON cycle to maintain the dimming profile. That is, the microprocessor 220 is able to continue implementing the dimming profile despite the temporary power interruption because of the previously saved most current values of set-points upon occurrence of the loss of power event.

[0065] When the measured capacitor voltage is less than the pre-determined threshold (block S415: No), the microprocessor 220 determines (by inference) in block S418 that it is returning from an extended power outage, as discussed above, and therefore restarts the dimming profile in block S419 that was being implemented before the occurrence of the loss of power event. In an embodiment, the dimming profile may be restarted using the turn-ON and turn-OFF events to estimate ON cycles and/or the starting and stopping of the night cycle. Alternatively, restarting the dimming profile may require user input for proper initiation.
In block S420, the same input/output pin 221 of the microprocessor 220 is configured as an analog output, and is set to "high" value, after determining whether or not the loss of power event was a temporary power interruption. This charges the timing capacitor 231 back to the predetermined voltage (e.g., the supply voltage Vcc of the microprocessor 220) during a subsequent normal operating mode in block S421, thus preparing for the next loss of power event (indicated by arrow returning to block S411).

Embodiments of the interruption timing circuit, together with the microprocessor, may be used in an LED driver, for example, that adjusts output current according to a dimming profile, which is based on a timing sequence and relies on counting time between events. This may be especially beneficial in products used in regions where loss of power events are more frequent. Embodiments of the interruption timing circuit inform the microprocessor whether power has been off long enough (during a loss of power event) to be considered an extended power outage, as opposed to merely a temporary power interruption, by comparing capacitor voltage after the power turn-off event to a predetermined threshold. The time of the last valid ON cycle before a temporary power interruption may be saved in order to determine the relative time in the dimming profile where the microprocessor should be, and therefore enable the microprocessor to follow the dimming profile correctly despite the occurrence of the temporary power interruption and/or the respective lengths of back-to-back valid ON cycles. Also, in certain embodiments, the interruption timing circuit enables the microprocessor to calculate how long the power has been off (lost time) during a temporary power interruption, e.g., by calculating the actual time required to discharge the timing capacitor to the measured capacitor voltage (as opposed to simply comparing the capacitor voltage to the predetermined threshold). The interruption timing circuit may be incorporated into any products, in addition to LED drivers and other lighting products, that have similar requirements of "weeding-out" temporary power interruptions from among various loss of power events, while following a timed sequence of events (dimming profile) during operation.

While several 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. 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.

[0069] 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.

[0070] 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."

[0071] 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.
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.

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.

Also, reference numerals appearing in the claims in parentheses, if any, are provided merely for convenience and should not be construed as limiting the claims in any way.
CLAIMS:

1. A system for controlling an electrical circuit, subject to a loss of power event, the system comprising:
   a microprocessor configured to control operation of the electrical circuit according to a dimming profile, the microprocessor comprising a plurality of input/output pins;
   a timing capacitor connected to one input/output pin of the plurality of input/output pins of the microprocessor, the timing capacitor charging to a predetermined voltage via the one input/output pin when uninterrupted power is applied to the microprocessor before the loss of power event, and discharging at a fixed discharge rate from the predetermined voltage to a discharge voltage during the loss of power event; and
   a discharge resistor connected in parallel with the timing capacitor through which the timing capacitor discharges during the loss of power event,

   wherein the microprocessor is configured to measure the discharge voltage of the timing capacitor via the one input/output pin, and to determine that the loss of power event was a temporary power interruption when the measured discharge voltage of the timing capacitor is above a predetermined threshold, enabling continued operation of the electrical circuit according to the dimming profile.

2. The system of claim 1, wherein the microprocessor is further configured to determine that the loss of power event was an extended power outage, preventing continued operation of the electrical circuit according to the dimming profile, when the sampled discharge voltage of the timing capacitor is below the predetermined threshold.

3. The system of claim 1, wherein the microprocessor is further configured to retain a last operating set-point prior to the loss of power event, and to continue operation of the electrical circuit according to the dimming profile using the retained last operating set-point when the loss of power event is determined to have been the temporary power interruption.
4. The system of claim 2, wherein the microprocessor is further configured to restart the dimming profile when the loss of power event is determined to have been the extended outage.

5. The system of claim 1, further comprising:
   a charge resistor connected between the timing capacitor and the one input/output pin of the microprocessor, the charge resistor being configured to limit an amount of current flowing out of the timing capacitor into the one input/output pin, reducing error caused by protection diode current through a protection diode connected to the one input/output pin within the microprocessor.

6. The system of claim 5, wherein the charge resistor has a larger resistance value than the discharge resistor.

7. The system of claim 1, wherein the predetermined voltage of the timing capacitor is the same as a supply voltage of the microprocessor.

8. The system of claim 1, wherein the loss of power event causes the microprocessor to shut down.

9. The system of claim 1, wherein the electrical circuit comprises at least one light emitting diode (LED) and a LED driver, connected to the microprocessor, for driving the at least one LED at a plurality of different LED currents according to the dimming profile.

10. The system of claim 9, wherein the dimming profile causes the microprocessor to control the LED driver to drive the at least one LED at a lower current during a low traffic time period and at a higher current during a high traffic time period.
11. A method of operating a microprocessor configured to control an electrical circuit according to a dimming profile, a timing capacitor being connected in parallel with a discharge resistor between an input/output pin of the microprocessor and ground voltage, the method comprising:

configuring the input/output pin of the microprocessor as an analog input at power-up of the microprocessor after being shut-down;

measuring a voltage across the timing capacitor at the input/output pin;

when the measured voltage is greater than a predetermined threshold voltage, determining that the microprocessor is returning from a temporary power interruption and continuing to control the electrical circuit according to the dimming profile as before the microprocessor was shut-down,

wherein the timing capacitor discharges at a fixed discharge rate while the microprocessor is power shut-down.

12. The method of claim 11, further comprising:

when the measured voltage is less than the predetermined threshold, determining that the microprocessor is returning from an extended power outage, requiring restarting of the dimming profile.

13. The method of claim 12, further comprising:

reconfiguring the input/output pin of the microprocessor as an analog output, and charging the timing capacitor from the input/output pin to a supply voltage of the microprocessor in preparation for a subsequent shut-down of the microprocessor.

14. The method of claim 11, wherein the electrical circuit comprises a light emitting diode (LED) and a LED driver configured to drive the LED at a plurality of different LED currents according to the dimming profile.
15. The method of claim 11, further comprising:
calculating a length of time of the temporary power interruption based on the measured voltage across the timing capacitor at the input/output pin.

16. The method of claim 15, further comprising:
adding the last saved ON time before the preceding power outage length of time back into the dimming profile, and continuing to control the electrical circuit according to the dimming profile by returning to the correct point in the profile.

17. A method of characterizing a loss of power event, incurred by an electrical circuit controlled by a microprocessor according to a predetermined dimming profile, using a timing capacitor connected to a microprocessor pin of the microprocessor, the method comprising:
charging the timing capacitor to a predetermined voltage during a normal operating mode when uninterrupted power is applied to the microprocessor before the loss of power event;
sampling a voltage of the timing capacitor at the microprocessor pin when powering-up after the loss of power event, wherein the timing capacitor discharges at a fixed discharge rate through a parallel connected discharge resistor during the loss of power event;
determining whether the loss of power event was a temporary power interruption based on the sampled voltage; and
continuing operation of the electrical circuit according to the predetermined dimming profile when the loss of power event is determined to have been the temporary power interruption,

wherein charging the timing capacitor is performed using the microprocessor pin configured as an output pin, and sampling the voltage of the timing capacitor is performed using the microprocessor pin configured as an input pin.
18. The method of claim 17, further comprising:
restarting the predetermined dimming profile when the loss of power event is
determined not to have been the temporary power interruption.

19. The method of claim 17, further comprising:
charging the timing capacitor back to the predetermined voltage during a subsequent
normal operating mode after determining whether the loss of power event was a temporary
power interruption.
FIG. 1
FIG. 2
Start

Experience loss of power event during normal operation S411

Save operation parameters including time of ON-cycle S412

Configure I/O pin as analog input at power-up S413

Measure voltage across timing capacitor at I/O pin S414

Volt > threshold? S415

Yes

Determine returning from temporary power interruption S416

Continue to control electrical circuit according to dimming profile S417

No

Reconfigure I/O pin as analog output S420

Charge timing capacitor to predetermined voltage S421

Determine returning from extended power outage S418

Restart dimming profile executed by microprocessor S419

FIG. 4
INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER

INV. H05B37/02
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)
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 practicable, search terms used)
EPO-Internal , WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
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<tr>
<th>Category</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
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<td>X</td>
<td>GB 2 427 767 A (TRIDONICATCO GMBH &amp; CO KG [AT]) 3 January 2007 (2007-01-03) pages 6-11; figures 1, 4</td>
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* 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 application or patent 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

"Z" document member of the same patent family

Date of the actual completion of the international search: 25 March 2015

Date of mailing of the international search report: 01/04/2015

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See patent family annex.
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