(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 2 739 120 A1

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
04.06.2014 Bulletin 2014/23

(51) Int Cl.:
H05B 33/08 *(2006.01)*

(21) Application number: **12195229.5**

(22) Date of filing: **03.12.2012**

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME

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(54) Controlling operation of a light source

(57) An approach for providing a control signal for a power converter, the power converter being adapted to supply an output current for driving a light source on basis of the control signal, wherein the output current comprises a series of cycles, each cycle consisting of an active period followed by a non-active period is provided. The approach comprises setting the control signal to cause the power converter to supply the active period of a given cycle of the output current employing an active period of a desired duration, receiving an indication of the observed duration of the active period in the given cycle of the output current, determining the difference between the observed duration of the active period of the given cycle of the output current and the desired duration of the active period of the given cycle of the output current on basis of said indication, determining the target duration of the given cycle of the output current on basis of said determined difference to provide a desired duty cycle in the given cycle of the output current, and setting the control signal to cause the power converter to initiate the next cycle of the output current after supplying the given cycle of said target duration

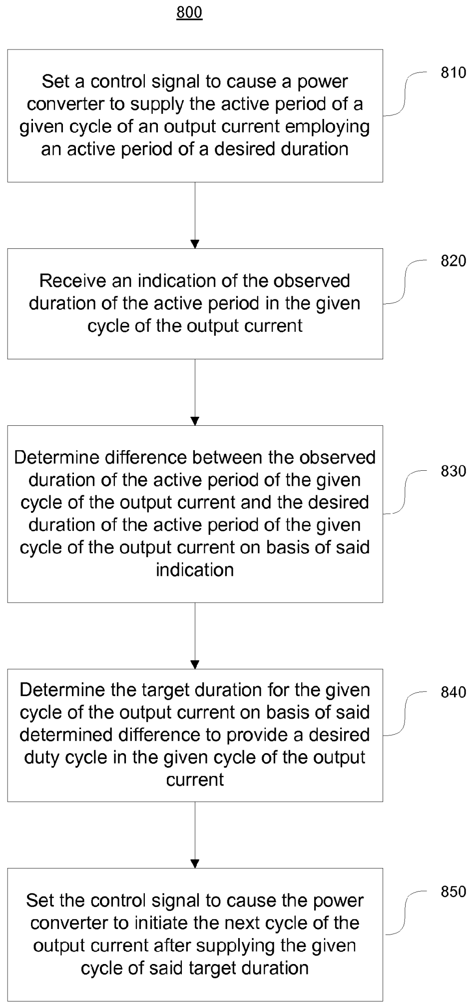

Figure 8

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Description

FIELD OF THE INVENTION

[0001] The invention relates to control of operation of one or more light sources, in particular one or more light emitting diodes (LED).

BACKGROUND OF THE INVENTION

[0002] A driver for driving one or more light sources may apply a control signal, such as a pulse-width modulation (PWM) signal, for controlling the light intensity provided by the one or more light sources, i.e. for controlling the dimming operation of the one or more light sources. A periodic PWM signal where a signal cycle of desired characteristics with respect to its amplitude and duration is typically applied as the control signal, such that the duty cycle of the PWM signal is used as a basis for determining the duty cycle of an output current provided to the one or more light sources, which in turn determines the level of light intensity provided by the one or more light sources.

[0003] However, in practical implementations the duty cycle of the output current may deviate from that indicated by the control signal. Possible deviation between the desired duty cycle and the actually applied duty cycle may occur e.g. due to delay in processing or inherent slowness of components of the power converter or possible other intervening entities between the control entity and the one or more light sources. Moreover, inherent characteristics of the system, e.g. ones related to operating frequencies of the control entity, the power converter and/or the control signal itself may have an effect on the output current as provided to the one or more light sources, thereby resulting in a dimming behavior different from the one intended. Disturbances in the output current may further contribute to changes in the provided light level that may be perceived e.g. as sudden changes in the light level and/or flickering of light.

SUMMARY OF THE INVENTION

[0004] It is an object of the present invention to provide an approach that facilitates ensuring that the control signal as received at the one or more light sources provides an output current resulting in the desired dimming characteristics, thereby contributing to providing light at a desired light intensity in an undisturbed manner.

[0005] The objects of the invention are reached by apparatuses, by a method and a computer program as defined by the respective independent claims.

[0006] According to a first aspect of the invention, an apparatus for providing a control signal for a power converter, the power converter being adapted to supply an output current for driving a light source on basis of the control signal, wherein the output current comprises a series of cycles, each cycle consisting of an active period followed by a non-active period is provided. The apparatus comprises a signal provision portion for providing the control signal and a signal timing portion for adjusting the control signal. The signal provision portion is configured to set the control signal to cause the power converter to supply the active period of a given cycle of the output current employing an active period of a desired duration. The signal timing portion is configured to receive an indication of the observed duration of the active period in the given cycle of the output current, to determine the difference between the observed duration of the active period of the given cycle of the output current and the desired duration of the active period of the given cycle of the output current on basis of said indication, and to determine the target duration of the given cycle of the output current on basis of said determined difference to provide a desired duty cycle in the given cycle of the output current. The signal provision portion is further configured to set the control signal to cause the power converter to initiate the next cycle of the output current after supplying the given cycle of said target duration.

[0007] According to a second aspect of the invention, an apparatus for driving a light source is provided, the apparatus comprising a power converter portion adapted to receive a control signal and to supply an output current for driving a light source on basis of the control signal, wherein the output current comprises a series of cycles consisting of an active period followed by a non-active period, and an apparatus according to the first aspect of the invention.

[0008] According to a third aspect of the invention, an apparatus for providing a control signal for a power converter, the power converter being adapted to supply an output current for driving a light source on basis of the control signal, wherein the output current comprises a series of cycles, each cycle consisting of an active period followed by a non-active period, the apparatus comprising at least one processor and at least one memory including computer program code for one or more programs, the at least one memory and the computer program code configured to, with the at least one processor, cause the apparatus at least to set the control signal to cause the power converter to supply the active period of a given cycle of the output current employing an active period of a desired duration, to receive an indication of the observed duration of the active period in the given cycle of the output current, to determine the difference between the observed duration of the active period of the given cycle of the output current and the desired duration of the active period of the given cycle of the output current on basis of said indication, to determine the target duration of the given cycle of the output current on basis of said determined difference to provide a desired duty cycle in the given cycle of the output current, and set the control signal to cause the power converter to initiate the next cycle of the output current after supplying the given cycle of said target duration.

[0009] According to a fourth aspect of the invention, a method for providing a control signal for a power converter, the power converter being adapted to supply an output current for driving a light source on basis of the control signal, wherein the output current comprises a series of cycles, each cycle consisting of an active period followed by a non-active period is provided. The method comprises setting the control signal to cause the power converter to supply the active period of a given cycle of the output current employing an active period of a desired duration, receiving an indication of the observed duration of the active period in the given cycle of the output current, determining the difference between the observed duration of the active period of the given cycle of the output current and the desired duration of the active period of the given cycle of the output current on basis of said indication, determining the target duration of the given cycle of the output current on basis of said determined difference to provide a desired duty cycle in the given cycle of the output current, and setting the control signal to cause the power converter to initiate the next cycle of the output current after supplying the given cycle of said target duration.

[0010] According to a fifth aspect of the invention, a computer program for providing a control signal for a power converter, the power converter being adapted to supply an output current for driving a light source on basis of the control signal, wherein the output current comprises a series of cycles, each cycle consisting of an active period followed by a non-active period, the computer program including one or more sequences of one or more instructions which, when executed by one or more processors, cause an apparatus at least to set the control signal to cause the power converter to supply the active period of a given cycle of the output current employing an active period of a desired duration, to receive an indication of the observed duration of the active period in the given cycle of the output current, to determine the difference between the observed duration of the active period of the given cycle of the output current and the desired duration of the active period of the given cycle of the output current on basis of said indication, to determine the target duration of the given cycle of the output current on basis of said determined difference to provide a desired duty cycle in the given cycle of the output current, and to set the control signal to cause the power converter to initiate the next cycle of the output current after supplying the given cycle of said target duration.

[0011] The computer program may be embodied on a volatile or a non-volatile computer-readable record medium, for example as a computer program product comprising at least one computer readable non-transitory medium having program code stored thereon, the program code, which when executed by an apparatus, causes the apparatus at least to perform the operations described hereinbefore for the computer program in accordance with the fifth aspect of the invention.

[0012] The exemplifying embodiments of the invention presented in this patent application are not to be interpreted to pose limitations to the applicability of the appended claims. The verb "to comprise" and its derivatives are used in this patent application as an open limitation that does not exclude the existence of also unrecited features. The features described hereinafter are mutually freely combinable unless explicitly stated otherwise.

[0013] The novel features which are considered as characteristic of the invention are set forth in particular in the appended claims. The invention itself, however, both as to its construction and its method of operation, together with additional objects and advantages thereof, will be best understood from the following detailed description of specific embodiments when read in connection with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014]

Figure 1 illustrates an example of a pulse-width modulation signal.

Figure 2 schematically illustrates an exemplifying arrangement in accordance with an embodiment of the invention.

Figure 3 schematically illustrates an exemplifying driver apparatus in accordance with an embodiment of the invention.

Figure 4 schematically illustrates an exemplifying driver apparatus in accordance with an embodiment of the invention.

Figure 5 schematically illustrates an exemplifying controller portion in accordance with an embodiment of the invention.

Figure 6 illustrates an example of a relationship between an input PWM signal and an output PWM signal.

Figure 7 illustrates an example of adjustment of the duration of a cycle of the input PWM signal.

Figure 8 illustrates a method in accordance with embodiment of the invention.

Figure 9 schematically illustrates an apparatus in accordance with an embodiment of the invention.

Figure 10 schematically illustrates a buck converter as example of a power converter portion in accordance with an embodiment of the invention.

DETAILED DESCRIPTION

[0015] Figure 2 schematically illustrates an exemplifying arrangement 200 comprising a controller portion 210, a power converter portion 220, a feedback portion 230 and one or more light sources 240. The controller portion 210 is configured, among other things, to provide a control signal 215 for providing indication of a desired light intensity or a desired light level to the power converter 220. The controller portion 210 is preferably configured to receive an input signal for controlling its operation, e.g. by indicating the desired light intensity or the desired light level to be indicated in the control signal 215. The power converter portion 220 is configured to receive operating power input and the control signal 215 and to prepare and supply an output current 225 based at least in part on the operating power and on the control signal 215. The operating power may originate, for example, from a suitable external source of electric current, depending on the type and characteristics of the power converter portion 220. Hence the external source may be an AC source, such as the mains current or another source of AC, or the external source may be a DC source, possibly derived on basis of the mains current or another AC source. The feedback portion 230 is configured to observe or monitor the output current 225 and to provide information on one or more observed characteristics of the output current 225 to the controller portion 210 in a feedback signal 235. Consequently, the controller portion 210 is configured to adjust the characteristics of the control signal 215 in accordance with the feedback signal 235.

[0016] The output current 225 is provided for the one or more light sources 240 in order to provide light intensity in accordance with the duty cycle of the output current 225. In particular, the light intensity provided by the one or more light sources may be directly proportional to the duty cycle of the output current 225 with e.g. the 100 % duty cycle resulting in the one or more light sources 240 providing their full light intensity and e.g. 30 % duty cycle resulting in the one or more light sources 240 providing 30 % of their full light intensity. The mapping between the duty cycle and the proportion of full light intensity is not necessarily direct as in the example provided hereinbefore, but depending on the characteristics of the one or more light sources 240 the mapping from a duty cycle into a corresponding percentage of the full light intensity of the one or more light sources 240 may follow an increasing function different from direct one-to-one mapping exemplified hereinbefore.

[0017] The control signal 215 may be, in principle, any signal that may be employed to control the operation of the power converter such that the output current 225 exhibits a desired duty cycle or at least approximates the desired duty cycle. An example of such a control signal is a periodic or a quasi-periodic signal exhibiting a sequence of periods, i.e. cycles, with each cycle comprising an on-period having the duration t_{on} during which the control signal 215 is at a 'high' level and an off-period having the duration t_{off} during which the control signal 215 is at a 'low' level. In more generic terms, the on-period may be considered to represent the active period of a cycle and the off-period may be considered to represent the non-active period of the cycle, and such a control signal hence exhibits a sequence of alternating active periods and non-active periods. Consequently, the control signal 215 may cause the power converter portion 220 to supply the output current 225 at a predetermined level in response to an active period of the control signal 215 and to supply the output current 225 at zero level during a non-active period of the control signal 215, thereby providing the output current 225 exhibiting a duty cycle approximating that of the control signal 215.

[0018] As an example in this regard, the control signal may be a pulse-width modulation (PWM) signal, as illustrated by an example in Figure 1. The example provided in Figure 1 schematically illustrates a periodic square wave PWM signal exhibiting a sequence of periods, i.e. cycles, with each cycle exhibiting an active period having the duration t_{on} during which the PWM signal is at a 'high' level and a non-active period having the duration t_{off} during which the PWM signal is at a 'low' level. Moreover, the PWM signal exhibits a constant or essentially constant cycle duration t_c. The duty cycle D of a single cycle of the PWM signal may be determined as the ratio of duration of the active period and the overall duration of the cycle, i.e. as

$$D = \frac{t_{on}}{t_c}.$$

[0019] Although Figure 1 depicts a PWM signal with a constant duty cycle, the duty cycle of a PWM signal may vary or may be varied over time. If considering a plurality of cycles having active periods with durations $t_{on}(i)$, non-active periods with durations $t_{off}(i)$ and overall cycle duration t_c with $i=1...N$, the overall duty cycle D_N may be defined as

$$D_N = \frac{1}{N}\sum_{i=1}^{N}\frac{t_{on}(i)}{t_c}.$$

[0020] In other words, the duty cycle may be determined as the ratio of the duration of the active periods of one or more cycles and the overall duration of the one or more cycles of the PWM signal.

[0021] While the example of Figure 1 illustrates an ideal square wave PWM signal as example of a signal suitable as the control signal 215, a control signal comprising a sequence of alternative active periods and non-active periods different from a PWM signal may be employed. In particular, the control signal 215 may be a square wave signal different from a PWM signal or the pulses of the control signal 215, typically representing the active periods of the control signal 215, need not have a square wave shape or an approximation thereof. Hence, various types of control signals, possibly exhibiting pulse shapes different from square wave pulses (or approximations thereof), applicable for controlling the power converter portion 220 may be employed. Moreover, the cycle duration of the control signal 215 need not be fixed but it may vary from cycle to cycle.

[0022] Hence, in general the control signal 215 may be considered to be at the 'high' level or active when electric current and/or a voltage of the control signal 215 meets one or more predetermined criteria, whereas the control signal 215 may be considered to be at the 'low' level or non-active when the electric current and/or the voltage of the control signal 215 fails to meet the one or more predetermined criteria. As an example of the one or more predetermined criteria, the control signal 215 may be considered to meet the predetermined criteria when its electric current exceeds a threshold current and/or when its voltage exceeds a threshold voltage. Conversely, in such an exemplifying case the control signal 215 fails to meet the predetermined criteria when its electric current fails to exceed the threshold current and/or its voltage fails to exceed the threshold voltage. Consequently, in general the control signal 215 may be considered to comprise a series of cycles, with cycle i having overall duration $t_c(i)$ and consisting of an active period having duration $t_{on}(i)$, a non-active period having duration $t_{off}(i)$. The duty cycle of a single cycle of such a control signal may be determined as

$$D(i) = \frac{t_{on}(i)}{t_c(i)},$$

whereas the duty cycle for a plurality of cycles may be determined as

$$D_N = \frac{\sum_{i=1}^{N} t_{on}(i)}{\sum_{i=1}^{N} t_c(i)}.$$

[0023] The controller portion 210, the power converter portion 220 and the feedback portion 230 may be considered as portions of a driver apparatus 250 for driving the one or more light sources 240, as schematically illustrated in Figure 3. The driver apparatus 300 typically comprises further portions or components in addition to ones schematically illustrated in the arrangement 200. As an example, the driver apparatus 300 comprises an arrangement for coupling the one or more light sources 240 to the driver apparatus 300, in particular an arrangement for coupling the one or more light sources 240 such that the output current 225 is provided as the driving signal for the one or more light sources 240 either directly or via one or more intervening components or elements. For clarity and brevity of description, the arrangement for coupling the one or more light sources 240 to the driver apparatus 300 may be referred to as the output of the driver apparatus 300.

[0024] The driver apparatus 300 may further comprise a feedback arrangement between the output of the driver apparatus 250 and the power converter portion 220 in order to provide a feedback signal further controlling the operation of the power converter portion 220, as known in the art. This feedback signal may be provided by the feedback portion 230 or the driver apparatus 250 may be provided with a dedicated feedback circuitry for this purpose.

[0025] Moreover, the driver apparatus 300 typically further comprises an arrangement for coupling the power converter portion 220 to a source of operating power. In case the power converter portion 220 requires a DC voltage and the source of operating power, such as the mains current, provides an AC voltage, the driver apparatus 300 may comprise a rectifier circuitry for converting the AC voltage into a DC voltage. Furthermore, depending on the type of the driver apparatus 300 and the one or more light sources 240 it is arranged to drive the driver apparatus 300 may further comprise a power factor correction circuitry.

[0026] The one or more light sources 240 may be for example one or more LED light sources and hence the driver apparatus 300 may be LED driver apparatus for driving one or more LED light sources. In general, the one or more light sources 240 may be any dimmable lights sources for which the dimming functionality may be provided by supplying the output current 225 comprising alternative periods of electric current at a predetermined level and periods of zero current and the driver apparatus 300 may be provided as a driver apparatus having characteristics suitable for driving the one or more light sources 240 of the respective type.

[0027] As a variation of the exemplifying driver apparatus schematically illustrated in Figure 3, the controller portion 210 may be provided in a controller apparatus 400, whereas the power converter portion 220 and the feedback portion 230 may be considered as portions of a driver apparatus 300' for driving the one or more light sources 240, as schematically illustrated in Figure 4. The differences to the arrangement involving the driver apparatus 300 include that the control signal 215 is now passed between the control portion 210 at the controller apparatus 400 and the power converter portion 220 at the driver apparatus 300', whereas the feedback signal 235 is passed between the feedback portion 230 at the driver apparatus 300' and the control portion 210 at the controller apparatus 400. Otherwise the operation of the arrangement illustrated in Figure 4 is similar to that described in context of the arrangement 200 and the driver apparatus 300.

[0028] As an exemplifying further variation of the arrangements illustrated in Figure 3 and 4, the feedback portion 230 or one or more components thereof may be provided outside the driver apparatus 300, 300', e.g. as a dedicated feedback apparatus or a feedback module that may be coupled to the driver apparatus 300, 300' and/or to the controller apparatus 400.

[0029] Figure 5 schematically illustrates the controller portion 210. The controller portion 210 comprises a signal provision portion 212 for composing and providing the control signal 215 and a signal timing portion 214 for adapting or adjusting the characteristics of the control signal 215 in accordance with the feedback signal 235. The controller portion 210 may be considered as an apparatus for controlling the power converter portion 220 by providing the control signal 215 thereto, where the power converter portion 220 is configured to receive the control signal 215 and to determine the output current 225 for driving the one or more light sources 240 with the output current 225 determined at least in part on basis of the control signal 215. Moreover, as described hereinbefore, the output current comprises a series of cycles, each cycle consisting of an active period and a non-active period. In particular, each cycle may be considered to consist of an active period followed by a non-active period.

[0030] In the following, the operation of the controller portion 210 is described by using a control signal exhibiting a sequence of alternating active periods and non-active periods, e.g. a control signal as described hereinbefore. This choice is made for clarity and brevity of description, while control signal of different type or characteristics may be applied within scope of the present invention.

[0031] The signal provision portion 212 is configured to provide the control signal 215. In particular, the signal provision portion 212 is configured to initiate the active period of a given cycle of the control signal 215, the given cycle comprising an active period of a desired duration. Preferably, if assuming a nominal cycle duration t_{ref}, the cycle *k* of the control signal 215 is initiated at a desired duty cycle $D_{in}(k)$, the cycle *k* hence exhibiting the active period having the desired duration $t_{on}(k) = D_{in}(k) \times t_{ref}$. Moreover, the non-active period of cycle *k* may be initiated immediately after completion of the active period thereof. The non-active period has a nominal duration $t_{off}(k) = t_{ref} - t_{on}(k)$, but the duration of the period $t_{off}(k)$ may be modified in response to an indication received in the feedback signal 235, as will be described in more detail hereinafter. In more generic terms, the signal provision portion 212 is configured to set the control signal 215 into a state that instructs the power converter portion 210 to initiate and supply the cycle *k* of the output current 225 such that the duration of the active period of the cycle *k* employs or at least approximates the desired duration.

[0032] The desired duty cycle $D_{in}(k)$ may be determined, for example, on basis of an input signal provided to the signal provision portion 212. As an example, the input control signal may originate from a user-operable control interface that enables adjusting the dimming level, which in turn causes the controller portion 210 to cause the signal provision portion 212 to adjust the desired duty cycle $D_{in}(k)$ of the input control signal 215 in accordance with the input control signal. As another example, the desired duty cycle $D_{in}(k)$ may be determined on basis of one or more input signals originating from one or more sensors. Such sensors may be e.g. light sensors configured to sense the prevailing level of ambient light and the processing portion 210 may be configured to determine the current desired duty cycle $D_{in}(k)$ in dependence of the observed level of ambient light. Details of determining the desired duty cycle on basis of control input from a user-operable control interface, from a sensor or from other source are outside of the scope of the present invention and such arrangements are known in the art.

[0033] While in theory an observed duty cycle $D_{out}(k)$ of the output current 225 is equal or essentially equal to the desired duty cycle $D_{in}(k)$, in a real-life situation there may be a difference e.g. due to processing applied in the power converter portion 220 or e.g. in other portions or elements of the driver apparatus 300, 300'. In case the observed duty cycle $D_{out}(k)$ is equal or substantially equal to the desired duty cycle $D_{in}(k)$, the signal provision portion 212 is, typically, configured to continuously provide the control signal 215 exhibiting active periods of duration $t_{on}(k)$ using the reference cycle duration t_{ref}. The observed duty cycle $D_{out}(k)$ of the output current 225 or a parameter indicative thereof may be determined on basis of the feedback signal 235, as briefly referred to hereinbefore and described in more detail hereinafter.

[0034] The signal provision portion 212 is preferably configured to provide the control signal 215 on basis of a predetermined timer or clock, hence on basis of a reference signal exhibiting a predetermined sampling frequency f_{clock}. The sampling frequency f_{clock} enables expressing the reference cycle duration t_{ref} and the duration of the active period $t_{on}(k)$ as respective number of timer/clock ticks, determined as $t_{ref} \times f_{clock}$ and $t_{on}(k) \times f_{clock}$, respectively. The reference cycle duration t_{ref} is preferably selected to constitute an integer number of timer/clock ticks. In case the duration of the active period $t_{on}(k)$ determined on basis of the desired duty cycle $D_{in}(k)$ as $t_{on}(k) = D_{in}(k) \times t_{ref}$ does not provide an integer number of timer/clock ticks $t_{on}(k) \times f_{clock}$, it is preferably rounded to the nearest integer number of timer/clock ticks.

[0035] A cycle frequency f_{cycle}, i.e. the number of cycles per second, of the control signal 215 is typically in the range from 100 Hertz to 1 kilohertz. Unnecessary low cycle frequency f_{cycle} is likely to cause flickering of light in the one or more light sources 240, while on the other hand unnecessarily high cycle frequency f_{cycle} is likely to increase disturbances due to operation of the power converter portion 220 or other components of the driver 300, 300', thereby possibly increasing deviation between the desired duty cycle $D_{in}(k)$ and the observed duty cycle $D_{out}(k)$.

[0036] The power converter portion 220 is preferably configured to supply the output current 225 during the active periods of the cycles of the control signal provided thereto. Hence, the power converter portion 220 may be configured to convert the operating power provided thereto at a first voltage into a second voltage for provision at the output of the power converter 220 during active periods of the control signal 215. Consequently, the output current 225 exhibits alternating periods of active and non-active periods such that the periods of the output current 225 corresponding to the active periods of the control signal 215 exhibit a non-zero current, preferably a predetermined non-zero current, whereas the periods of the output current 225 corresponding to the non-active periods of the control signal 215 exhibit zero current or essentially zero current. In this regard, the control signal 215 may be configured to control operation of one or more switches of the power converter portion 220 e.g. such that the operation of the power converter portion 220 is enabled or active only during active periods of the control signal 215 while the operation of the power converter portion 220 is disabled or inactive during non-active periods of the control signal 215.

[0037] Alternatively, the power converter portion 220 may be configured to continuously convert the operating power provided thereto at a first voltage into a second voltage for provision at the output of the power converter portion 220 and to generate and supply the output current 225 on basis of the converted voltage, i.e. the second voltage, in dependence of the control signal 215 such that the periods of the output current 225 corresponding to the active periods of the control signal 215 exhibit a non-zero current whereas the periods of the output current 225 corresponding to the non-active periods of the control signal 215 exhibit zero current or essentially zero current. In this regard, the control signal 215 may be configured to control operation of output of the power converter portion 220 e.g. such that the output of the power converter portion 220 is enabled or active only during active periods of the control signal 215 while the output of the power converter portion 220 is disabled or inactive during non-active periods of the control signal 215.

[0038] As a variation of the approaches for the control signal enabling or disabling the operation or output of the power converter portion 220, the operation may be reversed from the one described hereinbefore such that a non-active period of a cycle of the control signal 215 results in an active period of the corresponding cycle output current 225 whereas an active period of a cycle of the control signal 215 results in a non-active period of the corresponding cycle of the output current 225.

[0039] The power converter portion 220 may be embodied as a step-down converter configured to convert the operating power provided as input thereto at the first voltage into a driving signal exhibiting the second voltage, which second voltage is lower than the first voltage. A step-down converter may be embodied as a buck converter or another suitable converter for converting a first DC voltage into a second DC voltage, which second DC voltage is lower than the first DC voltage. Such power converters are known in the art. As an example in this regard, Figure 10 schematically illustrates a buck converter that may be applied as the power converter portion 220. The exemplifying buck converter receives the operating power via the input V_{in} and comprises a switch S, a diode D, an inductor L and a capacitor C. The driving circuitry DRV is arranged to operate, i.e. to periodically open and close, the switch S in a suitable manner in order to result in a desired output current to be provided via the inductor L to the light emitting diode D_{LED} coupled to the exemplifying buck converter. As referred to hereinbefore, the input control signal 215 may be provided as an input to the driving circuitry DRV, and the driving circuitry DRV is configured to operate the switch S to provide the output current 225 during active periods of the control signal 215, while on the other hand the driving circuitry DRV is configured to keep the switch S in open state during non-active periods of the control signal 215, thereby providing the output current 225 as zero current or current that is essentially zero. Suitable driving circuits are known in the art, and further details regarding the operation logic of the driving circuit DRV are outside the scope of the present invention.

[0040] However, due to delay caused by processing in the power converter 220, an active period of the control signal 215 and the corresponding active period of the output current 225 may be not be temporally aligned. Moreover, the processing applied at the power converter portion 220 may also result in distortions and variations in the amplitude of the output current 225, e.g. in the level of electric current and/or in the voltage of the output current 225. Possible other portions of the driver apparatus 300, 300' may incur further disturbances causing further deviation between the cycles of the control signal 215 and the corresponding cycles of the output current 225 as provided at the output of the driver apparatus 300, 300'. An origin of the delay may be for example a capacitor within the power converter portion 220 taking some time to be fully charged in order to start supplying an output current when the power converter portion 210 is activated. Another example of an origin of delay within the power converter portion 210 is an inductive element which typically results in delay in both activating and inactivating the power converter portion 220 or operation thereof.

[0041] One reason for variation in amplitude and duration of the active periods coming out from the power converter portion 220 is the internal switching operation applied e.g. in a buck converter and other switched mode power supplies. Such a power converter applies an (internal) switching frequency that typically is in the order of tens or hundreds of kilohertz, e.g. in a range from 50 to 250 kilohertz. This switching operation of the power converter may result in a periodic ripple during the active periods of the output current 225 at the (internal) switching frequency of the power converter. Moreover, since the (internal) switching frequency, which is controlled by a dedicated control logic partially relying on feedback from the load the power supply is feeding, e.g. the one or more light sources 240, is typically not fully constant, the reaction time in changing from an active period to a non-active period within a cycle of the output current 225 may exhibit small variations due to varying (internal) switching frequency, possibly resulting in deviation between the desired duty cycle $D_{in}(k)$ and the observed duty cycle $D_{out}(k)$. This, in turn, is likely to result in variation of light level provided by the one or more light sources 240, especially on low values of the desired duty cycle $D_{in}(k)$.

[0042] Figure 6 schematically illustrates an example of deviation in duration between the control signal 215 and the output current 225. Due to the delay and/or the distortions, for a given cycle *k* the beginning of the active period of the control signal 215, denoted as $T_{up\text{-}in}(k)$, is typically not temporally aligned with the beginning of the active period of the respective cycle of the output current 225, denoted as $T_{up\text{-}out}(k)$ and/or the end of the active period of the control signal 215, denoted as $T_{dn\text{-}in}(k)$, is typically not temporally aligned with the end of the active period of the respective cycle of the output current 225, denoted as $T_{dn\text{-}out}(k)$. The time difference in the beginning of the active period for the given cycle *k* may be denoted as $t_{diff\text{-}up}(k) = T_{up\text{-}out}(k) - T_{up\text{-}in}(k)$ and the time difference in the end of the active period may be denoted as $t_{diff\text{-}dn}(k) = T_{dn\text{-}out}(k) - T_{dn\text{-}in}(k)$.

[0043] As briefly referred to hereinbefore, the feedback portion 230 is configured to observe or monitor the output current 225 and to provide information on one or more observed characteristics of the output current 225 to the processing portion 210 in a feedback signal 235. As an example in this regard, the feedback portion 230 may be configured to provide an a feedback signal 235 that serves as an indication of the beginning of an active period $T_{up\text{-}out}(k)$ in the output current 225 and/or as an indication of the end of an active period $T_{dn\text{-}out}(k)$ in the output current 225. As another example, the feedback portion 230 may be configured to provide the feedback signal 235 comprising an indication of observed duration of the active period in a given cycle of the output current 225. Preferably, the feedback portion 230 is configured to provide the feedback signal 235 regarding each cycle of the output current 225.

[0044] In particular, the feedback portion 230 may be configured to carry out zero-current detection in the output current 225 and to provide the controller portion 210 with the feedback signal 235 indicative of the zero-current being detected in the output PWM signal 225. In contrast, while non-zero current is being detected, the feedback signal 235 may indicate current different from zero being detected in the output current 225. Hence, the change of the feedback signal 235 from a state indicating non-zero current into a state indicating zero current serves to indicate the end of an active period in the output current 225 and the change of the feedback signal 235 from the state indicating zero current into the state indicating non-zero current serves to indicate the beginning of an active period in the output current 225. As a variation of such approach, instead of detecting current of exactly zero, the detection may monitor and detect current exceeding or falling below a predetermined threshold and change the state of the feedback signal 235 accordingly. Detection of a zero current or a current falling short of the predetermined may rely, for example, on one or more current sensing resistors coupled to a circuit arrangement configured to convert the sensed level of electric current into a suitable feedback signal 235. Such arrangements are known in the art.

[0045] As another example, the feedback portion 230 may be configured to detect the output current 225 exhibiting a voltage and/or a level of electric current meeting predetermined criteria to qualify as an active period and to provide to the processing portion 210 a feedback signal 235 indicative of such voltage and/or level of electric current being detected in the output current 225. Consequently, the processing portion 210 may determine the beginning and/or end of an active period in the output current 225 on basis of the feedback signal 235 provided thereto.

[0046] The feedback signal 235 may be provided from the feedback portion 230 to the signal timing portion 214 using a physical electrical connection between these portions. Additionally or alternatively, the feedback signal 235 may be provided to the signal timing portion 214, via an arrangement that enables physical separation between the feedback portion 230 and the controller portion 210. Such an arrangement may comprise, for example, an optocoupler for transferring the feedback signal 235 as light waves or a transformer arrangement for transferring the feedback signal 235 by electrical induction. Such an arrangement may be provided as part of the feedback portion 230 or in the signal path between the feedback portion 230 and the controller portion 210.

[0047] The signal timing portion 214 is configured to receive an indication of the observed duration of the active period in the cycle *k* of the output current 225. As an example, the indication provided in the feedback signal 225 may directly indicate the observed duration of the active period in the cycle *k* of the output current. As another example, such indication may comprise an indication of the end of an active period in cycle *k* of the output current 225, which is a cycle of the output current 225 corresponding to cycle *k* of the control signal 215. Such indication may be received in the feedback signal 235 or such an indication may be derived on basis of the feedback signal 235. Additionally, the signal timing portion 214 may be configured to receive an indication of the beginning of the active period in cycle *k* of the output current 225 corresponding to the cycle *k* of the control signal 215.

[0048] The time difference in the beginning of the active period $t_{diff\text{-}up}(k)$ typically remains constant or essentially constant from cycle to cycle, and hence it may not be necessary for the signal timing portion 214 to receive and/or the feedback portion 230 to provide information required to determine $_{tdiff\text{-}up}(k)$ and/or for the signal timing portion 214 to determine $t_{diff\text{-}up}(k)$ even in case the determination of the duration of the active period in the cycle *k* relies on indication(s) regarding the end and/or beginning of the active period. Instead, as an example, the information required to determine the value of $t_{diff\text{-}up}(k)$ may be provided only during one or more initial cycles of the output current 225, the value of $t_{diff\text{-}up}(k)$ determined on basis of the information provided for these initial cycles and the determined value of $t_{diff\text{-}up}(k)$ used subsequently. As a variation of such an approach, the information required to determine the value of $t_{diff\text{-}up}(k)$ may be provided periodically and the value of $t_{diff\text{-}up}(k)$ updated accordingly. In other words, the value of $t_{diff\text{-}up}(k)$ may be determined on basis of one or more cycles preceding the cycle *k*. for subsequent use in determination of the observed duration of the active period in the cycle *k* of the output current 225. On the other hand, the signal timing portion 214 may be configured to determine the value of $t_{diff\text{-}up}(k)$ for the cycle *k* on basis of indication(s) determined on basis of the cycle *k* of the output current 225.

[0049] With the feedback signal 235 providing indication(s) that enable detecting the moment of time when the output current 225 changes from an active period to a non-active period and/or vice versa and the signal timing portion 214 having access to the timing information of the commencing and termination of the active period of the control signal 215 supplied by the signal provision portion 212, the signal timing portion 214 may be configured to determine the observed duration of the active period of the cycle *k* of the output current 225, the desired duration of the active period of the cycle *k* as provided in the control signal 215. Consequently, on basis of this information the signal timing portion is able to determine the difference between the observed duration of the active period and the desired duration of the active period. In particular, the signal timing portion 214 may be configured, for the given cycle *k*, to determine the time differences $t_{diff\text{-}up}(k)$ and/or $t_{diff\text{-}dn}(k)$, as described hereinbefore to be employed as basis of determination of the difference between the observed and desired durations.

[0050] Hence, in case the observed duration and the desired duration of the active period are the same or essentially the same, e.g. in case the time difference in the beginning of a cycle $t_{diff\text{-}up}(k)$ and in the end of the cycle $t_{diff\text{-}dn}(k)$ are the same or essentially the same, the output current 225 may be considered to correspond to the control signal 215 in terms of exhibiting the desired duty cycle $D_{in}(k)$ to a sufficient extent and hence corrective actions in this regard are typically not necessary. Consequently, the signal provision portion 212 may initiate the next cycle of the control signal 215, i.e. cycle $k+1$ after the reference cycle duration t_{ref} since the beginning of cycle *k*, i.e. at $T_{up\text{-}in}(k+1) = T_{up\text{-}in}(k) + t_{ref}$ in order to cause the power converter portion 220 to supply the cycle $k+1$ of the output current 225 after the reference cycle duration t_{ref} since the beginning of cycle *k*, i.e. at $T_{up\text{-}out}(k+1) = T_{up\text{-}out}(k) + t_{ref}$.

[0051] On the other hand, in case the observed duration is different from the desired duration, e.g. if the time differences in the beginning of a cycle $t_{diff\text{-}up}(k)$ and in the end of the cycle $t_{diff\text{-}dn}(k)$ exhibit a difference, the signal timing portion 214 may be configured to adjust the remaining part of the cycle *k* in response in order to bring the duty cycle $D_{out}(k)$ of the output current 225 at or closer to the desired duty cycle $D_{in}(k)$. As an example, the absolute value of the difference between the desired duration of the active period and the observed duration of the active period in the output current 225 defined as $t_{diff\text{-}on}(k) = t_{diff\text{-}dn}(k) - t_{diff\_up}(k)$ exceeding a predetermined threshold may be considered as an indication of the observed duty cycle $o_{out}(k)$ of the output current 225 being different from the desired duty cycle $o_{in}(k)$ to an extent that requires corrective measures to be taken. As an example, the predetermined threshold may be one timer/clock tick. As another example, the predetermined threshold may be several timer/clock ticks in case small variation in the duty cycle of the output current 225 can be allowed. As a special case, the predetermined threshold may be zero, implying that any difference between the duration of the active period of a given cycle of the control signal 215 and duration of the active period of the respective cycle of the output current 225 results in adjustment of the remaining part of the given cycle of the control signal 215.

[0052] Consequently, the signal timing portion 214 may be configured to adjust the duration of the non-active period of the cycle *k* and/or timing of the active period for the cycle $k+1$ of the control signal 215 in order to force the duty cycle of the output current 225 to the desired value or at least closer to the desired value, i.e. to a value matching or essentially matching the desired duty cycle $D_{in}(k)$.

[0053] In this regard, the processing portion 210 may be configured to determine the difference between the desired duration of the active period and the observed duration of the active period in the output current 225 as indicated by $t_{diff\text{-}on}(k)$ and to determine the adjustment period as

$$t_{adj}(k) = \frac{t_{diff-on}(k)}{t_{on}(k)} t_{ref},$$

e.g. as the ratio between the difference between the duration of the active period of the control signal 215 and that of the output current 225 and the duration of the active period of the control signal 215 for cycle *k*, multiplied by the reference cycle duration t_{ref}. Note that since the duty cycle of the cycle *k* can be written as

$$D(k) = \frac{t_{on}(k)}{t_{ref}},$$

the adjustment period may be determined as

$$t_{adj}(k) = \frac{t_{diff-on}(k)}{D(k)},$$

where the desired duty cycle $D_{in}(k)$ may be applied as the duty cycle $D(k)$.

[0054] Hence, the signal timing portion 212 may be configured to determine the target duration to be applied for the cycle *k* of the output current 225 e.g. on basis of the difference between observed duration of the active period and the desired duration of the active period of the cycle *k* and the duration of the active period of the cycle *k* of the control signal 215. As an alternative, the signal timing portion 212 may be configured to determine the target duration for the cycle *k* of the output current 225 via determining a target duration for the non-active period of the cycle *k* and determining the target duration for the cycle *k* as the sum of the observed duration of the active period of the cycle *k* in the output current 225 and the target duration for the non-active period of the cycle *k*. Moreover, the signal provision portion 212 may be configured to realize the adjustment by changing the duration of the non-active period in cycle *k* and hence the cycle *k* of the control signal 215 by the amount indicated by the adjustment period $t_{adj}(k)$ by setting the control signal 215 to cause the power converter portion 220 to initiate the cycle *k+1* of the output current 225 after having supplied the cycle *k* of said target duration, e.g. after having applied the non-active period resulting in the determined target duration for the cycle *k*. This is illustrated by an example in Figure 7.

[0055] As an example, this may be realized instead of initiating the active period of cycle *k+1* of the control signal 215 after the reference cycle duration t_{ref} since the beginning of the active period of the cycle *k*, i.e. at $T_{up-in}(k) + t_{ref}$ by starting the cycle *k+1* at $T_{up\_in}(k) + t_{ref} + t_{adj}(k)$ in order to, effectively, change the duration of the non-active period $t_{off}(k)$ of the cycle *k* by the amount determined by the adjustment period $t_{adj}(k)$. Consequently, this results in the power converter portion 220 initiating the active period of the output current 225 at $T_{up-out}(k) + t_{ref} + t_{adj}(k)$ thereby adjusting the duty cycle of the output current 225 in the cycle *k* to a value matching or essentially matching the desired duty cycle $D_{in}(k)$. Hence, in case the active period observed in the output current 225 is shorter than the respective active period indicated in the control signal 215 the non-active period $t_{off}(k)$, and hence the duration of the cycle *k* is shortened, whereas in case the active period observed in the output current 225 is longer than the respective active period indicated in the control signal 215 the non-active period $t_{off}(k)$, and hence the duration of the cycle *k*, is extended.

[0056] The operations for determining the difference between the observed duration of the active period of the cycle *k* of the output current 225 and the desired duration of the active period of the cycle *k*, determining the target duration for the cycle *k* and setting the control signal 215 to cause supplying the next cycle, i.e. the cycle *k+1*, of the output current 225 after having supplied the cycle *k* of said target duration are preferably carried out for each cycle of the output current 225.

[0057] In the following, the adjustment of the cycle of the output current 225 is further illustrated by an example with numerical values. Assuming a desired duty cycle $D_{in}(k)$ to be 3 % with the reference cycle duration t_{ref} = 4 milliseconds and employing a timer/clock running at f_{clock} = 2 MHz , resulting reference cycle duration is 8000 timer/clock ticks. With the desired duty cycle $D_{in}(k)$ = 3 % the desired duration of the active period is 3 % x 8000 ticks = 240 ticks and, consequently, the duration of the non-active period is 8000 - 240 = 7760 ticks. If the duration of the active period of a given cycle of the output current 225 is actually 199 ticks, this may be observed in the signal timing portion 214 via the value of $t_{diff-on}(k)$, determined on basis of information received in the feedback signal 235, indicating the value $t_{diff-on}(k)$ = (199 - 240) = -41. Consequently, the signal timing portion 214 determines the adjustment period as $t_{adj}(k)$ = -41 / 240 * 8000 = -1367 ticks and provides this information to the signal provision portion 212 to enable shortening the non-active period of the input PWM signal 215 by -1367 ticks in order ensure the desired duty cycle $D_{in}(k)$ during the current cycle.

[0058] The operations, procedures and/or functions assigned to the structural units of the controller portion 210, e.g. to the signal provision portion 212 and to the signal timing portion 214, may be divided between these sub-portions in a different manner. Moreover, the controller portion 210 may comprise further sub-portions or sub-units that may be configured to perform some of the operations, procedures and/or functions assigned to the signal provision portion 212 and to the signal timing portion 214 in the description hereinbefore. On the other hand, the operations, procedures and/or functions assigned to the signal provision portion 212 and to the signal timing portion 214 may be assigned to a single sub-portion or to a single sub- unit within the controller portion 210.

[0059] In particular, the controller portion 210 may be provided as an apparatus for providing a control signal for the power converter portion 220 that is adapted to supply the output current 225 for driving the one or more light sources 240 on basis of the control signal 215, wherein the output current 225 comprises a series of cycles consisting of an active period followed by a non-active period, the apparatus comprising means for setting the control signal 215 to cause the power converter portion 220 to supply the active period of a given cycle of the output current 225 employing an active period of a desired duration, means for receiving an indication of the observed duration of the active period in the given cycle of the output current 225, means for determining the difference between the observed duration of the active period of the given cycle of the output current 225 and the desired duration of the active period of the given cycle of the output current 225 on basis of said indication, means for determining the target duration of the given cycle of the output current 225 on basis of said determined difference to provide a desired duty cycle $D_{in}(k)$ in the given cycle of the output current 225, and means for setting the control signal 215 to cause the power converter portion 220 to initiate the next cycle of the output current 225 after supplying the given cycle of said target duration.

[0060] At least some of the operations, procedures and/or functions assigned to the structural units described in the context of the controller portion 210, e.g. to the signal provision portion 212 and to the signal timing portion 214 may be provided as steps of a method. As an example of this regard, Figure 8 illustrates a method 800 for providing a control signal for the power converter portion 220, which power converter portion 220 is adapted to supply the output current 225 for driving the one or more light sources 240 on basis of the control signal 215, wherein the output current 225 comprises a series of cycles consisting of an active period followed by a non-active period.

[0061] The method 800 comprises setting the control signal 215 to cause the power converter portion 220 to supply the active period of a given cycle of the output current 225 employing an active period of a desired duration, as indicated in block 810. The method 800 further comprises receiving an indication of the observed duration of the active period in the given cycle of the output current 225, as indicated block 820. The method 800 further comprises determining the difference between the observed duration of the active period of the given cycle of the output current 225 and the desired duration of the active period of the given cycle of the output current 225 on basis of said indication, as indicated in block 830. The method 800 further comprises determining the target duration of the given cycle of the output current 225 on basis of said determined difference to provide a desired duty cycle $D_{in}(k)$ in the given cycle of the output current 225, as indicated in block 840. Finally, the method 800 comprises setting the control signal to cause the power converter portion 220 to initiate the next cycle of the output current 225 after supplying the given cycle of said target duration, as indicated in block 850. Variations of the method become apparent on basis of the description of the details of the corresponding operations, procedures and/or functions of the controller portion 210 hereinbefore.

[0062] As a non-limiting example, Figure 9 schematically illustrates an exemplifying apparatus 900 that may be employed for embodying the controller portion 210. The apparatus 900 comprises a processor 910 and a memory 920, the processor 910 being configured to read from and write to the memory 920. The apparatus 900 may further comprise a communication interface 930 enabling communication with one or more another apparatuses. The apparatus 900 may further comprise a user interface 840 for providing data, commands and/or other input to the processor 910 and/or for receiving data or other output from the processor 910. The apparatus 900 may comprise further components not illustrated in the example of Figure 9.

[0063] Although the processor 910 is presented in the example of Figure 9 as a single component, the processor 910 may be implemented as one or more separate components. Although the memory 920 is illustrated as single component, the memory 920 may be implemented as one or more separate components, some or all of which may be integrated/removable and/or may provide permanent/semi-permanent/ dynamic/cached storage.

[0064] The apparatus 900 may be embodied as a special-purpose or as a general purpose device with a sufficient processing capacity. Alternatively, the apparatus 900 may be embodied as an apparatus dedicated for operating as the controller portion 210 described hereinbefore.

[0065] The memory 920 may store a computer program 850 comprising computer-executable instructions that control the operation of the apparatus 900 when loaded into the processor 910 and executed by the processor 910. As an example, the computer program 850 may include one or more sequences of one or more instructions. The computer program 850 may be provided as a computer program code. The processor 910 is able to load and execute the computer program 850 by reading the one or more sequences of one or more instructions included therein from the memory 920. The one or more sequences of one or more instructions may be configured to, when executed by one or more processors, cause an apparatus, for example the apparatus 900, to implement the operations, procedures and/or functions described hereinbefore in context of the controller portion 210.

[0066] Hence, the apparatus 900 may comprise at least one processor 910 and at least one memory 920 including computer program code for one or more programs, the at least one memory 920 and the computer program code configured to, with the at least one processor 910, cause the apparatus 900 to perform the operations, procedures and/or functions described hereinbefore in context of the controller portion 210.

[0067] The computer program 850 may be provided independently of the apparatus, and the computer program 850 may be provided at the apparatus 900 via any suitable delivery mechanism. As an example, the delivery mechanism may comprise at least one computer readable non-transitory medium having program code stored thereon, the program code which when executed by an apparatus cause the apparatus at least implement processing to carry out the operations, procedures and/or functions described hereinbefore in context of the controller portion 210. The delivery mechanism may be for example a computer readable storage medium, a computer program product, a memory device a record medium such as a CD-ROM, a DVD, a corresponding optical media, an article of manufacture that tangibly embodies the computer program 850, etc. As a further example, the delivery mechanism may be a signal configured to reliably transfer the computer program 850.

[0068] Reference to a processor should not be understood to encompass only programmable processors, but also dedicated circuits such as field-programmable gate arrays (FPGA), application specific circuits (ASIC), signal processors, etc. Features described in the preceding description may be used in combinations other than the combinations explicitly described. Although functions have been described with reference to certain features, those functions may be performable by other features whether described or not. Although features have been described with reference to certain embodiments, those features may also be present in other embodiments whether described or not.

Claims

1. An apparatus for providing a control signal for a power converter, the power converter being adapted to supply an output current for driving a light source on basis of the control signal, wherein the output current comprises a series of cycles, each cycle consisting of an active period followed by a non-active period, the apparatus comprising
a signal provision portion for providing the control signal, configured to set the control signal to cause the power converter to supply the active period of a given cycle of the output current employing an active period of a desired duration,
a signal timing portion for adjusting the control signal, configured to
receive an indication of the observed duration of the active period in the given cycle of the output current,
determine the difference between the observed duration of the active period of the given cycle of the output current and the desired duration of the active period of the given cycle of the output current on basis of said indication, and
determine the target duration of the given cycle of the output current on basis of said determined difference to provide a desired duty cycle in the given cycle of the output current,
wherein the signal provision portion is configured to set the control signal to cause the power converter to initiate the next cycle of the output current after supplying the given cycle of said target duration.

2. An apparatus according to claim 1, wherein said control signal is provided as a signal comprising a series of cycles, each cycle consisting of an active period followed by a non-active period, and wherein a cycle of the control signal corresponding to the given cycle of the output current is provided with the active period of said desired duration and having said target duration.

3. An apparatus according to claim 2, wherein the control signal is provided as a square wave signal.

4. An apparatus according to claim 2 or 3, wherein said indication comprises an indication of the end of the active period in the given cycle of the output current.

5. An apparatus according to claim 4, wherein said indication of the end of the active period in the given cycle of the output current comprises an indication of the current provided to the light source changing from a state indicating non-zero current into a state indicating zero current.

6. An apparatus according to claim 4 or 5, wherein said difference between said observed duration and said determined duration is determined as the difference between a first duration and a second duration,
wherein the first duration is time difference between the end of the active period of the given cycle of the output current and the end of the active period of the corresponding cycle of the control signal, and
wherein the second duration is time difference between the beginning of the active period in a cycle of the output current and the beginning of the active period of the corresponding cycle of the control signal.

7. An apparatus according to claim 6, wherein said second duration is determined on basis of one or more cycles preceding the given cycle.

8. An apparatus according claim 6, wherein said indication further comprises an indication of the beginning of the active period in the given cycle of the output current, and wherein the second duration is determined on basis of the given cycle.

9. An apparatus according to any of claims 1 to 8, wherein determining the target duration of the given cycle comprises
determining an adjustment period as the ratio between said determined difference and said desired duty cycle, and
determining said target duration as a sum of a nominal cycle duration and said adjustment period, wherein said nominal cycle duration equals to the ratio between said desired duration of the active period and the desired duty cycle.

10. An apparatus for driving a light source, the apparatus comprising
a power converter portion adapted to receive a control signal and to supply an output current for driving a light source on basis of the control signal, wherein the output current comprises a series of cycles consisting of an active period followed by a non-active period, and

an apparatus according to any of claims 1 to 9.

11. An apparatus according to claim 10, further comprising a feedback portion configured to provide the signal timing portion with a feedback signal indicative of the observed duration of the active period in the given cycle of the output current.

12. An apparatus for providing a control signal for a power converter, the power converter being adapted to supply an output current for driving a light source on basis of the control signal, wherein the output current comprises a series of cycles, each cycle consisting of an active period followed by a non-active period, the apparatus comprising at least one processor and at least one memory including computer program code for one or more programs, the at least one memory and the computer program code configured to, with the at least one processor, cause the apparatus to perform at least the following:

set the control signal to cause the power converter to supply the active period of a given cycle of the output current employing an active period of a desired duration,
receive an indication of the observed duration of the active period in the given cycle of the output current,
determine the difference between the observed duration of the active period of the given cycle of the output current and the desired duration of the active period of the given cycle of the output current on basis of said indication,
determine the target duration of the given cycle of the output current on basis of said determined difference to provide a desired duty cycle in the given cycle of the output current, and
set the control signal to cause the power converter to initiate the next cycle of the output current after supplying the given cycle of said target duration.

13. A method for providing a control signal for a power converter, the power converter being adapted to supply an output current for driving a light source on basis of the control signal, wherein the output current comprises a series of cycles, each cycle consisting of an active period followed by a non-active period, the method comprising
setting the control signal to cause the power converter to supply the active period of a given cycle of the output current employing an active period of a desired duration,
receiving an indication of the observed duration of the active period in the given cycle of the output current,
determining the difference between the observed duration of the active period of the given cycle of the output current and the desired duration of the active period of the given cycle of the output current on basis of said indication,
determining the target duration of the given cycle of the output current on basis of said determined difference to provide a desired duty cycle in the given cycle of the output current, and
setting the control signal to cause the power converter to initiate the next cycle of the output current after supplying the given cycle of said target duration.

14. A computer program for providing a control signal for a power converter, the power converter being adapted to supply an output current for driving a light source on basis of the control signal, wherein the output current comprises a series of cycles, each cycle consisting of an active period followed by a non-active period, the computer program including one or more sequences of one or more instructions which, when executed by one or more processors, cause an apparatus to at least perform the following:

set the control signal to cause the power converter to supply the active period of a given cycle of the output current employing an active period of a desired duration,
receive an indication of the observed duration of the active period in the given cycle of the output current,
determine the difference between the observed duration of the active period of the given cycle of the output current and the desired duration of the active period of the given cycle of the output current on basis of said indication,
determine the target duration of the given cycle of the output current on basis of said determined difference to provide a desired duty cycle in the given cycle of the output current, and
set the control signal to cause the power converter to initiate the next cycle of the output current after supplying the given cycle of said target duration.

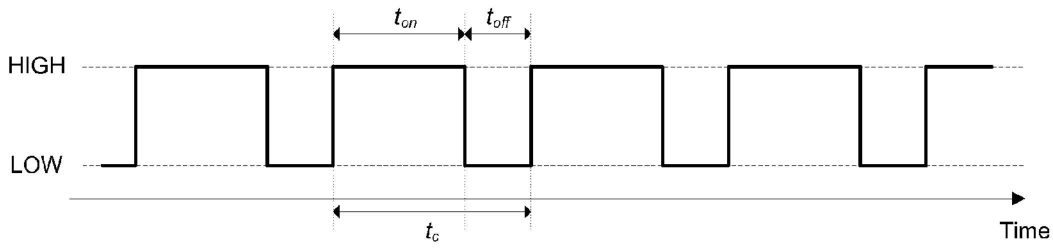

Figure 1

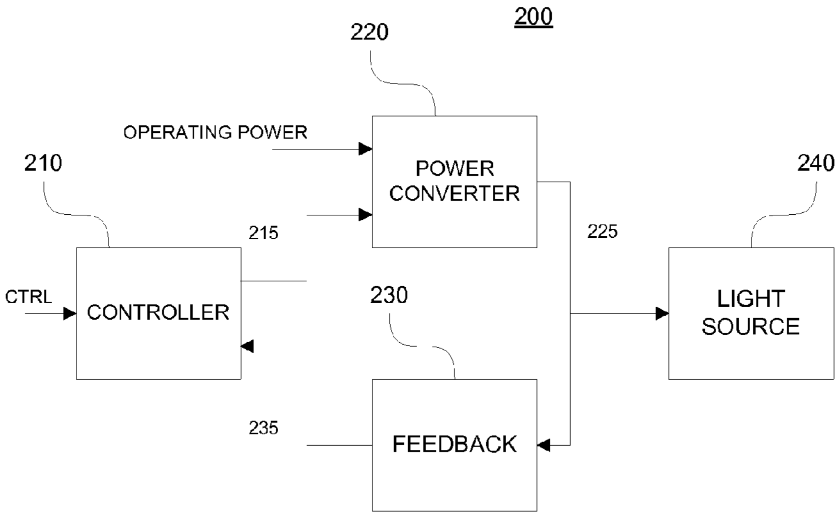

Figure 2

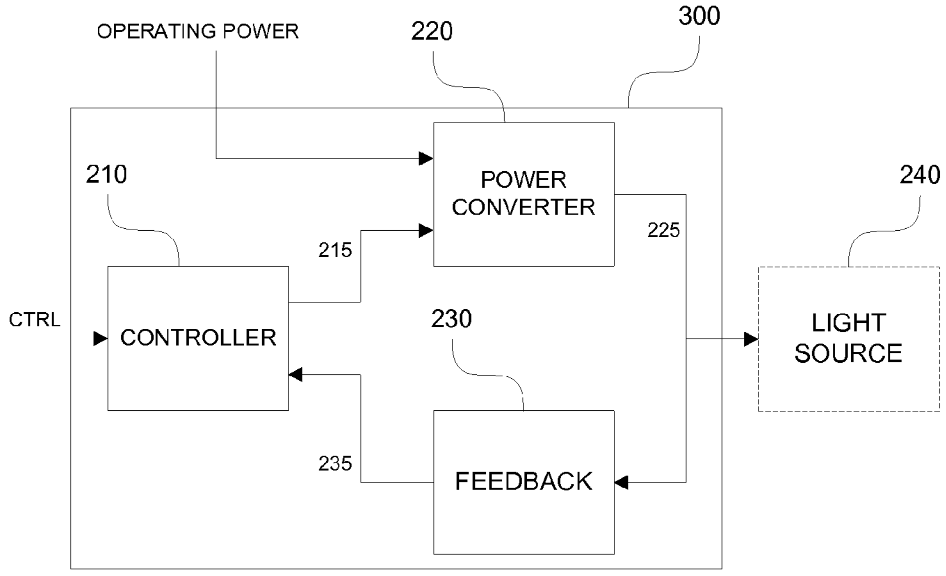

Figure 3

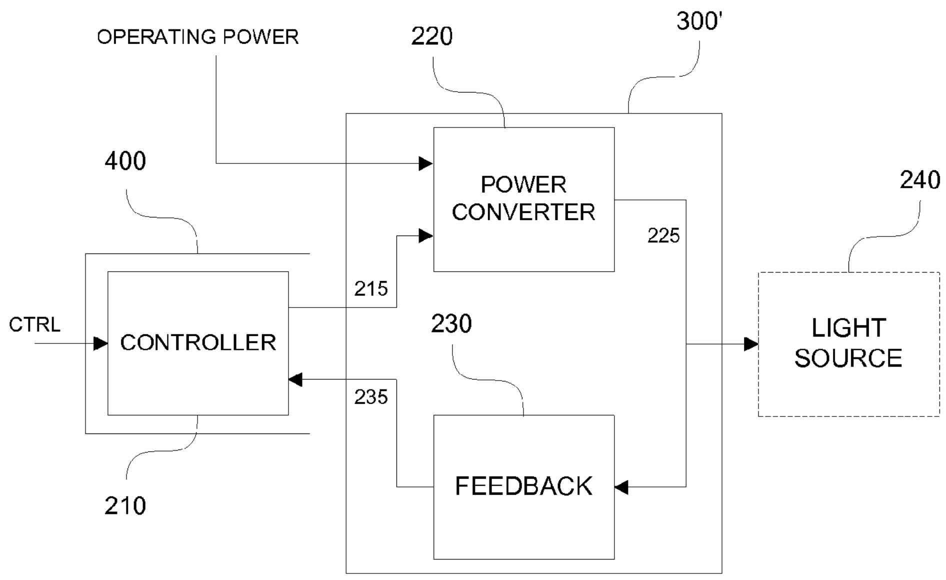

Figure 4

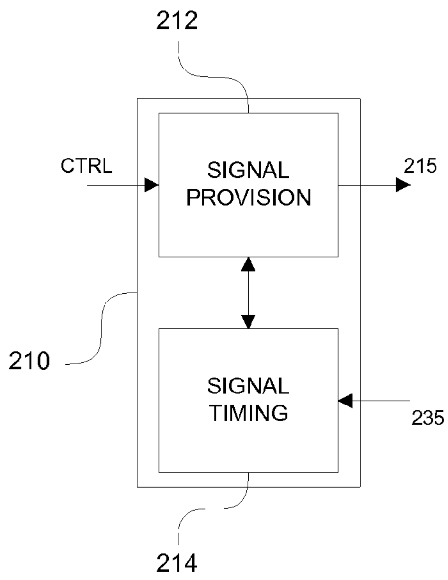

Figure 5

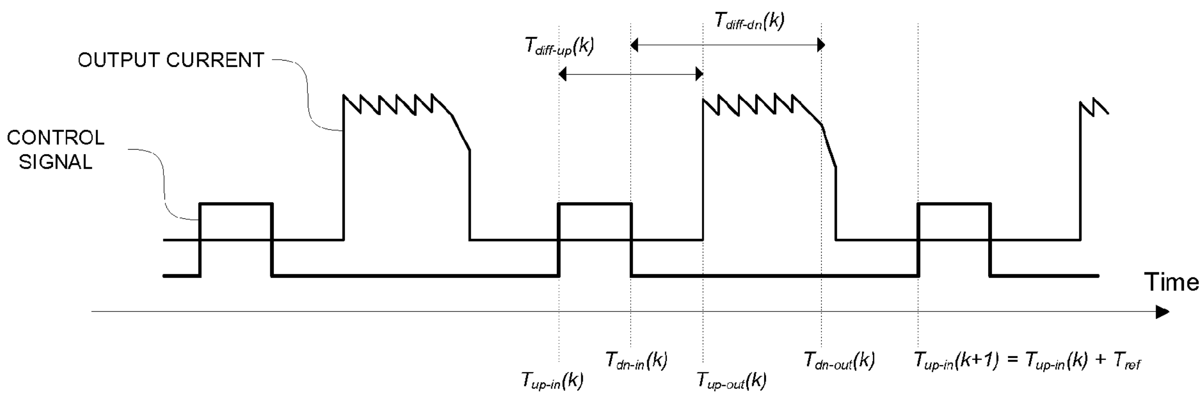

Figure 6

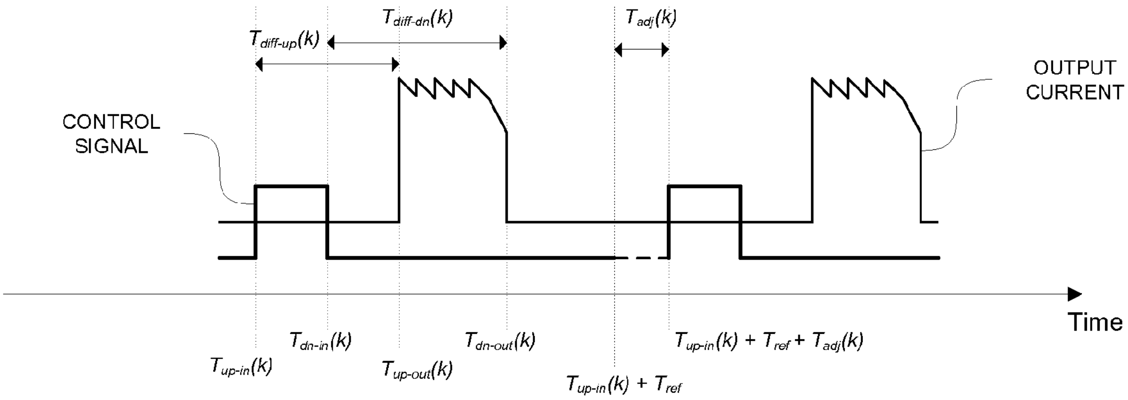

Figure 7

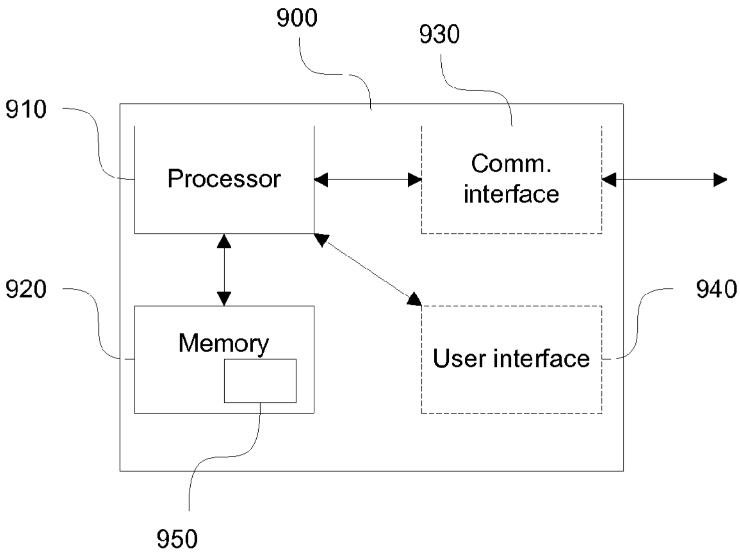

Figure 9

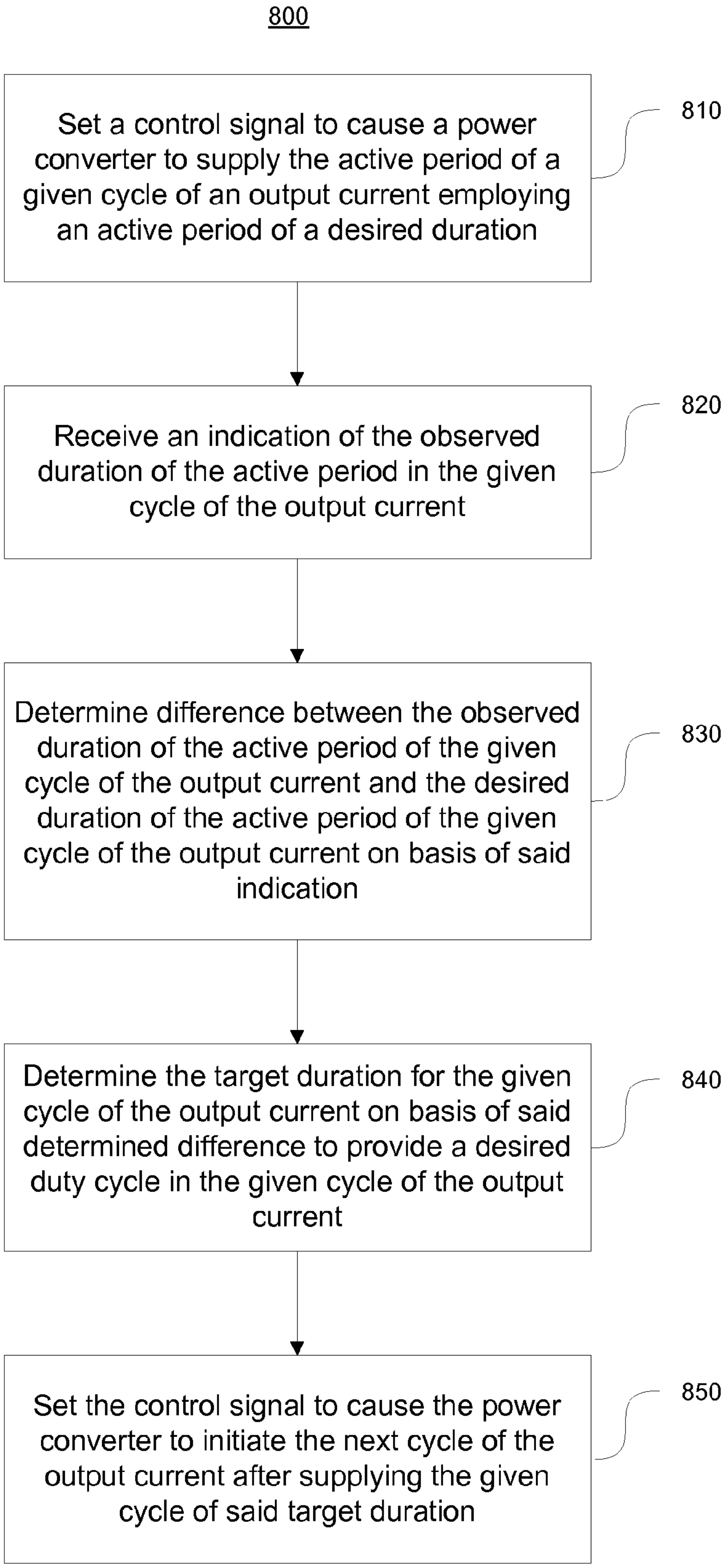
800
Set a control signal to cause a power converter to supply the active period of a given cycle of an output current employing an active period of a desired duration
810
Receive an indication of the observed duration of the active period in the given cycle of the output current
820
Determine difference between the observed duration of the active period of the given cycle of the output current and the desired duration of the active period of the given cycle of the output current on basis of said indication
830
Determine the target duration for the given cycle of the output current on basis of said determined difference to provide a desired duty cycle in the given cycle of the output current
840
Set the control signal to cause the power converter to initiate the next cycle of the output current after supplying the given cycle of said target duration
850

Figure 8

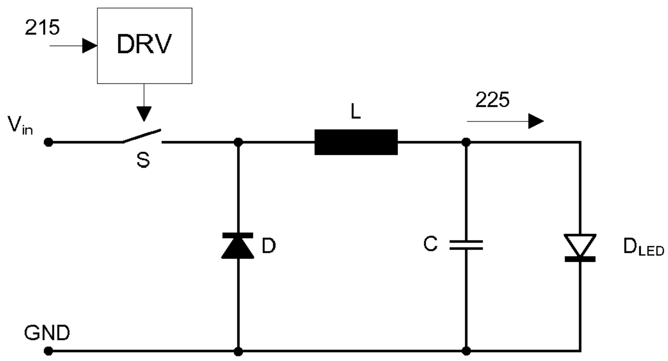

Figure 10

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EUROPEAN SEARCH REPORT

Application Number
EP 12 19 5229

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	US 2012/019154 A1 (CHEN CHIEN-YANG [TW] ET AL) 26 January 2012 (2012-01-26) * abstract * * figures 2-4,6,7 * * paragraphs [0005], [0021] - [0037] * -----	1-14	INV. H05B33/08
A	US 2009/184662 A1 (GIVEN TERRY [NZ] ET AL) 23 July 2009 (2009-07-23) * abstract * -----	1-14	

TECHNICAL FIELDS SEARCHED (IPC)

H05B

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
The Hague	18 April 2013	João Carlos Silva

CATEGORY OF CITED DOCUMENTS

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18-04-2013

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2012019154 A1	26-01-2012	TW 201206235 A	01-02-2012
		US 2012019154 A1	26-01-2012
		US 2012019155 A1	26-01-2012
US 2009184662 A1	23-07-2009	AT 536730 T	15-12-2011
		CN 101926221 A	22-12-2010
		CN 101926222 A	22-12-2010
		EP 2238807 A1	13-10-2010
		EP 2238808 A2	13-10-2010
		EP 2451250 A2	09-05-2012
		JP 2011510474 A	31-03-2011
		JP 2011510475 A	31-03-2011
		KR 20100107055 A	04-10-2010
		KR 20100126318 A	01-12-2010
		US 2009184662 A1	23-07-2009
		US 2009184666 A1	23-07-2009
		US 2011273095 A1	10-11-2011
		WO 2009094328 A2	30-07-2009
		WO 2009094329 A1	30-07-2009

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