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(54) Driving a light source

(57) According to an example embodiment, a driver apparatus for providing a driving current for one or more LEDs is provided. The apparatus comprises a power source portion for providing the driving current, the power source portion arranged to provide, when enabled, the driving current at a first level and a control portion for controlling the provision of the driving current to provide light output at a requested light level, the control portion configured to issue one or more control signals comprising a duty cycle based control signal to cause cyclically enabling and disabling provision of the driving current such that the average driving current corresponds to said requested light level, wherein the control portion is configured to modify characteristics of the driving current, in response to an indication of observed flickering of light in a location served by said one or more LEDs, such that the average driving current continues to correspond to said requested light level.

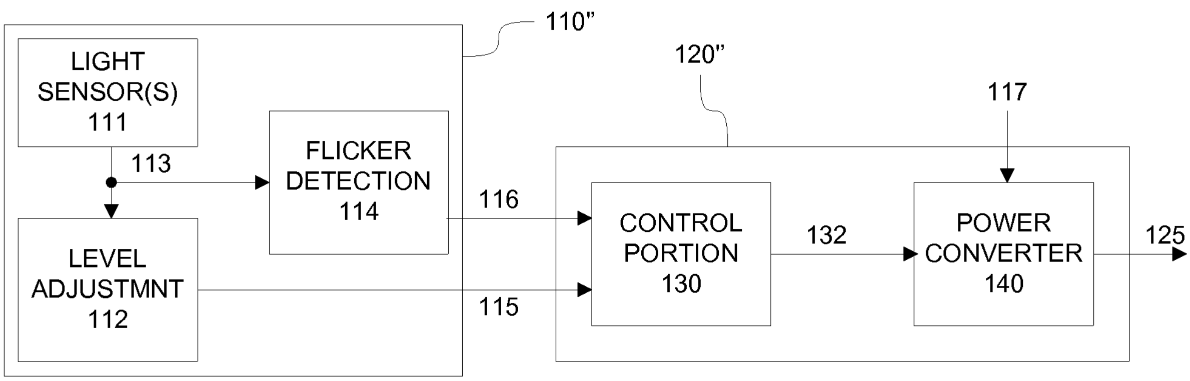

Figure 8

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Description

FIELD OF THE INVENTION

[0001] The invention relates to control of operation of one or more light emitting diode (LED) light sources by a driver apparatus. In particular, embodiments of the invention relate to a driver apparatus, a method for controlling a driver apparatus, a computer program for controlling a driver apparatus and a lighting arrangement involving one or more driving apparatuses.

BACKGROUND

[0002] A driver for a LED light source may apply a duty cycle based control signal, such as a pulse-width modulation (PWM) signal, for controlling the light intensity provided by the LED light source. A periodic PWM signal with desired duty cycle and cycle frequency (PWM frequency) is typically applied in the driver to cause the driver to operate the LED light source at a light intensity determined by the duty cycle. In practice such control of the LED light source, typically, results in switching the light on and off in accordance with active ('high') and non-active ('low') periods of the PWM signal. With sufficiently high PWM frequency the off periods are unperceivable by a human eye but rather contribute to perceived reduced light intensity (compared to driving the LED light source without the off periods).

[0003] However, especially at low duty cycles, i.e. at low values of perceived light intensity, too low PWM frequency is likely to result in perceivable flickering of light due to too long off periods between the on periods. This may even be perceived as a disturbing stroboscopic effect. On the other hand, too high PWM frequency is likely to result in inaccurate control of light intensity or even perceivable variations in light level due to switching operation of power converters typically applied in such drivers.

SUMMARY

[0004] Consequently, it is an object of the present invention to provide a technique for driving a LED light source in a location served by one or more further LED light source(s) such that the perceivable flickering and/or variations in perceived combined light output level are reduced or completely eliminated while keeping the combined light output level essentially unchanged.

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

[0006] According to a first example embodiment, a driver apparatus for providing a driving current for one or more LEDs is provided. The apparatus comprises a power source portion for providing the driving current, the power source portion arranged to provide, when enabled, the driving current at a first level and a control portion for controlling the provision of the driving current to provide light output at a requested light level, the control portion configured to issue one or more control signals comprising a duty cycle based control signal to cause cyclically enabling and disabling provision of the driving current such that the average driving current corresponds to said requested light level, wherein the control portion is configured to modify characteristics of the driving current, in response to an indication of observed flickering of light in a location served by said one or more LEDs, such that the average driving current continues to correspond to said requested light level.

[0007] According to a second example embodiment, a lighting arrangement is provided. The lighting arrangement comprises two or more driver apparatuses according to the first example embodiment and a flicker detection portion arranged to determine absence or presence of flickering on basis of a sensor signal indicative of the observed light level in the location served by said one or more LEDs and to provide the indication of observed flickering of light to said two or more driver apparatuses in response to determining presence of flickering.

[0008] According to a third example embodiment, a method for providing a driving current for one or more LEDs is provided, wherein the driving current is provided using a driver apparatus comprising a power source portion for providing the driving current, the power source portion arranged to provide the driving current at a first level.. The method comprises issuing one or more control signals for controlling the provision of the driving current to provide light output at a requested light level, said control signals comprising a duty cycle based control signal to cause cyclically enabling and disabling provision of the driving current such that the average of the driving current corresponds to said requested light level and modifying characteristics of the driving current, in response to an indication of observed flickering of light in a location served by said one or more LEDs, such that the average driving current continues to correspond to said requested light level.

[0009] According to a fourth example embodiment, a computer program for providing a driving current for one or more LEDs is provided. The computer program comprises one or more sequences of one or more instructions which, when executed by one or more processors, cause a driver apparatus comprising a power source portion for providing the driving current at least to perform the method according to the third example embodiment.

[0010] 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 an example embodiment.

[0011] 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.

[0012] 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

[0013] Some embodiments of the invention are illustrated by way of example, and not by way of limitation, in the figures of the accompanying drawings.

Figure 1 schematically illustrates some components of an exemplifying arrangement in accordance with an example embodiment.

Figure 2 schematically illustrates some components of a driver in accordance with an example embodiment.

Figure 3 illustrates an example of a Pulse-Width Modulation (PWM) signal.

Figure 4 schematically illustrates some components of an exemplifying buck converter.

Figure 5a illustrates an example of duty cycle based control signals in the same phases.

Figure 5b illustrates an example of duty cycle based control signals in opposite phases.

Figure 6 schematically illustrates some components of an exemplifying arrangement in accordance with an example embodiment.

Figure 7 schematically illustrates some components of a driver in accordance with an example embodiment.

Figure 8 schematically illustrates some components of a driver in accordance with an example embodiment.

Figure 9 schematically illustrates some components of an exemplifying arrangement in accordance with an example embodiment.

Figure 10 schematically illustrates some components of a driver in accordance with an example embodiment.

Figure 11 illustrates a method in accordance with an example embodiment.

Figure 12 schematically illustrates an apparatus in accordance with an example embodiment.

DESCRIPTION OF SOME EMBODIMENTS

[0014] Figure 1 schematically illustrates some components of an exemplifying arrangement 100 for providing light at a selectable light level. The arrangement 100 comprises sensor portions 110-1, 110-2, ..., 110-n for issuing respective input control signals 115-1, 115-2, ..., 115-n indicating desired characteristics of respective output currents to driver apparatuses 120-1, 120-2, ..., 120-n (drivers, in short). The sensor portions 110-1, 110-2, ..., 110-n are further configured to provide respective sensor signals 113-1, 113-2, ..., 113-n.

[0015] As an example regarding the numbering applied in this text, in the following the input control signals 115-1, 115-2, ..., 115-n may be referred to as input control signals 115 when referring jointly to all input control signals 115-1, 115-2, ..., 115-n or when referring to any single one of the input control signals 115-1, 115-2, ..., 115-n. Moreover, the reference number 115-i may be applied to refer to the i:th input control signal. Similar practice may be applied to any numbered element comprising multiple sub-elements, i.e. to reference number having the format xxx-i.

[0016] The driver 120 is arranged to receive the sensor signal 113 from the respective sensor portion 110. The drivers 120 are arranged to derive respective driving currents 125-1, 125-2, ..., 125-n on basis of operating power 117 provided thereto in accordance with the characteristics of the respective input control signal 115 and the sensor signal 113. The driving currents 125 are provided to respective arrays of light emitting diodes (LEDs) 170-1, 170,-2, ..., 170-n. An array of LEDs 170, in other words a LED array 170, comprises either a single LED light source or two or more light sources. In case of a LED array including multiple LED light sources, the LEDs may be connected in series or in parallel.

[0017] The LED arrays 170 may be arranged in a single luminaire, which is arranged to illuminate an area or space of interest. Alternatively, the LED arrays 170-i may be arranged into two or more luminaires arranged to illuminate the area or space of interest. Regardless of the arrangement of the respective LED arrays 170 into one or more luminaires, the drivers 120 are configured to operate independently of each other, in control of the respective input control signal 115, as will be described in more detail later in this text. The number n indicating the number of LED arrays 170 and hence the number of drivers 120 (as well as the number of sensor portions 110) in the arrangement 100 may be any number greater than or equal to two.

[0018] Figure 2 schematically illustrates some components of an exemplifying sensor portion 110. The sensor portion 110 comprises one or more light sensors 111, arranged in the area/space of interest to measure the light output from the LED arrays 170 in a desired location within the area/space of interest. Each light sensor 111 is arranged to provide a respective measurement signal indicative of the light level observed by the sensor 111, and the sensor portion 110 is arranged to provide the sensor signal 113 on basis of the measurement signal(s). In case of a single light sensor 111, the sensor signal 113 may be the measurement signal provided by the single light sensor 111 as such or a processed (e.g. lowpass filtered) version thereof. In case of a plurality of light sensors 111, the sensor signal 113 may be derived as a combination of the measurement signals from the plurality of light sensors 111, e.g. as a sum or as an average of the measurement signals. Moreover, the combination of the measurement signals may be further subjected to additional processing, such as (lowpass) filtering to derive the sensor signal 113. The light sensor(s) 111 of the sensor portion 110 are capable of providing measurement signals that enable detecting short-term variations in observed light level, e.g. flickering, at frequencies up to hundreds of Hertz. Such light sensors are known in the art.

[0019] The sensor portion 110 further comprises a light level adjustment portion 112 configured to derive the input control signal 115 for the respective driver 120 on basis of the sensor signal 113 and a predetermined target light level L_{tgt}. The target light level L_{tgt} may be set or defined e.g. upon installation or (re-)configuration of the driver 120 and/or the lighting arrangement 100. The light level adjustment portion 112 is arranged to issue input control signal(s) 115 for controlling the driver 120 such that the observed light level L_{obs} indicated by the sensor signal 113 approximates the target light level L_{tgt} as closely as possible. Hence, the light level adjustment portion 112 may be configured to operate e.g. in the following manner: in case the observed light level L_{obs} is lower than the target light level L_{tgt} (i.e. $L_{obs} < L_{tgt}$), the light level adjustment portion 112 issues in the input control signal 115 a command or request that causes the driver 120 to increase the light output level of the respective LED array 170. In contrast, in case the observed light level L_{obs} is higher than the target light level L_{tgt} (i.e. $L_{obs} > L_{tgt}$), the light level adjustment portion 112 issues in the input control signal 115 a command or request that causes the driver 120 to decrease the light output level of the respective LED array 170. In case the observed light level L_{obs} is equal (or essentially equal) to the target light level Ltgt (i.e. Lobs == L_{tgt}), the light level adjustment portion 112 may issue in the input control signal 115 a command or request that causes the driver 120 to keep the current light output level of the respective LED array 170 or, alternatively, to refrain from issuing a command in the input control signal 115 in order to keep the current light output level.

[0020] Although depicted in context of the arrangement 100 as a plurality of sensor portions 110, each arranged to provide the dedicated input control signal 115 and the sensor signal 113 to one of the drivers 120, a smaller number of sensor portions 110 may be applied such that at least some of the sensor portions 110 are arranged to provide the respective input control signal 115 and the sensor signal 113 to two or more drivers 120. As an example, there may be a single sensor portion 110 arranged to provide the input control signal 115 and the sensor signal 113 for all of the drivers 120.

[0021] The sensor portion 110 may be coupled to the driver(s) 120 via electric wires. As another example, the connection between the sensor portion 110 and the driver 120 may be a wireless one, employing e.g. a short-range wireless communication technique known in the art, such as Bluetooth (BT), Bluetooth Low Energy (BLE) or ZigBee. Although slightly more complex in structure, wirelessly connected sensor portion 110 allows providing the light sensors in a mobile entity that may be positioned according to each occasion in a most appropriate location and position.

[0022] The input control signals 115 may be provided in a number of ways and/or in a number of formats. Typically, however, the input control signal 115 is employed to provide a command or request in accordance with a lighting control protocol. As an example in this regard, the input control signal 115 may be a digital control signal applied to provide one or more commands according to, for example, the Digital Addressable Lighting Interface (DALI) protocol specified in Appendix E.4 of the International Electrotechnical Commission (IEC) standard 60929, in other words as one or more DALI commands. A DALI command provided in the input control signal 115-i may e.g. specify a desired or requested light intensity level associated with the driving current 125-i, thereby implying a request for a certain average current for the respective driving current 125-i. As another example, a DALI command provided in the input control signal 115 may specify a desired or requested change to be applied to the currently applied light intensity level. In particular, the DALI command requesting a certain light intensity or a certain change thereto may be considered to imply a request for an average current that is a certain percentage of the nominal output current of the driver 120-i. As an example, the nominal output current may be the maximum output current I_{max} of the driver 120-i. As further examples, a DALI command may be applied switch the LED array 170-i on or off.

[0023] As a further example, the input control signal 115 may be provided as a control signal comprising one or more commands according to the 1-10 V lighting control signaling, as described/specified in Appendix E.2 of the International Electrotechnical Commission (IEC) standard 60929. In such a signal the voltage of the input control signal 115-i may serve as an indication or as a request of the desired light intensity level associated with the respective driving current 125-i implying a request for a certain average current for the respective driving current 125-i. As in case of a DALI command, also the command according to the 1-10 V lighting control protocol may be considered to imply a request for an average current that is a certain percentage of the maximum output current I_{max} of the driver 120-i.

[0024] Figure 2 further schematically illustrates some components of the driver 120. The driver 120 comprises a power converter portion 140 for converting the operating power 117 supplied thereto into the driving current 125. The power converter portion 140 serves as a power source portion for providing the driving current 125. The driver 120 further comprises a control portion 130 for controlling provision of the driving current 125 in accordance with the input control signal 115 and the sensor signal 165.

[0025] The control portion 130 is configured to issue a control signal 132 for controlling provision of the driving current from the power converter portion 140 as a duty cycle based control signal exhibiting a predetermined cycle frequency f_c at a duty cycle D_{req}. An example of such a duty cycle based control signal is a PWM signal exhibiting the duty cycle D_{req} at the cycle frequency f_c. Figure 3 provides an example of a PWM signal, i.e. a rectangular wave signal consisting of a sequence of cycles, each cycle having an active period (active state, 'high' state) of duration t_{on}, a non-active period (non-active state, 'low' state) of duration toff, and overall duration t_c. The cycle duration t_c can be, alternatively, expressed as respective cycle frequency $f_c = 1 / t_c$ indicating the number of cycles per second. The duty cycle D_{req} may hence be expressed as $D_{req} = t_{on} / t_c = t_{on} * f_c$. The 'high' state may be provided e.g. as a voltage/current that is greater than or equal to a predetermined high threshold current while the 'low' state may be provided e.g. as a voltage/current that is smaller than or equal to a predetermined low threshold. As a specific example, assuming positive value of the high threshold, the low threshold may be set to zero.

[0026] While a PWM signal is typically applied as the duty cycle based control signal 132, a signal of other type exhibiting the desired duty cycle D_{req} may be employed as the duty cycle based control signal 132, e.g. a rectangular wave signal that does not exhibit strictly constant cycle duration t_c and therefore may not qualify as a PWM signal according a strict interpretation of the term and/or a signal comprising active periods that do not exhibit strictly rectangular shape.

[0027] The duty cycle D_{req} is, preferably, set in accordance with the input control signal 115. In case the input control signal 115 is provided or received as a signal comprising one or more DALI commands that imply specifying or requesting a certain light intensity level for the driving current 125, the control portion 130 may be configured to apply a predetermined mapping function to convert the specified/requested light intensity level into the duty cycle D_{req} to be applied in the duty cycle based control signal 132. Along similar lines, in case the input control signal 115 is provided or received as a signal comprising one or more commands according to the 1-10 V lighting control protocol specifying or requesting a certain light intensity level or a certain average current for the driving current 125, the control portion 130 may be configured to apply a(nother) predetermined mapping function to convert the specified/requested light intensity level into the duty cycle D_{req} to be applied in the duty cycle based control signal 132.

<u>*Cycle frequency of the control signal*</u>

[0028] The duty cycle based control signal 132 may employ a fixed predetermined cycle frequency f_c. The applied cycle frequency f_c may be e.g. a frequency selected from the range 150 to 1000 Hz. Alternatively, the control portion 130 may be arranged to employ cycle frequency f_c that is selected in accordance with the desired duty cycle D_{req}, e.g. such that a lower duty cycle implies a higher cycle frequency and vice versa. As an example regarding dependence between the cycle frequency f_c and the duty cycle D_{req} applied in the duty cycle based control signal 132, the control portion 130 may be configured to apply a first cycle frequency f_{c_H} if the duty cycle D_{req} is lower than a predetermined threshold duty cycle D_{TH} and to apply otherwise a second cycle frequency f_{c_L} that is lower than the first cycle frequency f_{c_H}. As another example, the control portion 130 may be configured to apply a mapping function for determining the cycle frequency f_c on basis of the duty cycle D_{req} such that a lower duty cycle implies a higher cycle frequency.

[0029] The power converter portion 140 may be arranged to provide an output current at a predetermined, constant (or essentially constant) level when it is active in providing the output current. A target value for the current provided from the power converter portion 140 when it is active in providing the output current (e.g. in an active state or enabled) may be denoted as I_{tgt_cnv}. In contrast, when the power converter portion 140 is inactive (e.g. in an inactive state or disabled), the output current therefrom is zero. The duty cycle based control signal 132 may be employed to control operating the power converter portion 140 either in the active state or the inactive state, as will be described in more detail later in this text. This power converter target current $I_{tgt\text{-}cnv}$ may be set to a predetermined fixed value or to a value selected upon installation or configuration of the driver 120 and/or the power converter portion 140. Typically, though, the driver 120, e.g. the control portion 130is provided with means for setting or adjusting the power converter target current I_{tgt_cnv} to enable providing the driving current 125 at a desired level. As an example in this regard, one or more level control signals may be applied between the control portion 130 and the driving circuit of the power converter portion 140 (which will be described later in this text) to adjust, set or select the power converter target current I_{tgt_cnv}. As another example, one or more parameter values within the control portion 130 may be set or adjusted to value(s) that cause controlling the power converter portion 140 (and or the above-mentioned driving circuit of the power converter portion 140) to provide current in accordance with the desired value of the power converter target current I_{tgt_cnv}. However, these are non-limiting examples and different means for the control portion 130 or another component of the driver setting or adjusting the current level provided from the power converter portion 140 may be applied instead.

[0030] Hence, the (average) level of the driving current 125 is dependent at least on the duty cycle D_{req} applied in the duty cycle based control signal 132 and the power converter portion target current I_{tgt_cnv}. In particular, the driving current 125 is varied between a high level that approximates the power converter portion target current I_{tgt_cnv} and a low level that is (typically) zero or essentially zero in accordance with the active and non-active periods of the duty cycle based control signal 132. Consequently, the average of the driving current 125 approximates $I_{tgt\_drv} = D\text{req} * I_{tgt\_cnv}$.

[0031] Thus, in addition to duty cycle based control using the duty cycle based control signal 132, the control portion 130 may be provided with means for setting or adjusting the power converter target current I_{tgt_cnv}. The control of the level of the output current from the power converter portion 140 may be referred to as linear control, level control or current level control As an example, setting the power converter portion target current $I_{tgt\text{-}cnv}$ may comprise setting suitable values for a high current limit I_{cnv_H} and a low current limit I_{cnv_L} that serve as upper and lower limits, respectively, of the power converter output current in the control loop of the power converter portion 140. The low current limit I_{cnv_L} may be e.g. set to zero or to a value slightly lower than the power converter target current $I_{tgt\text{-}cnv\ t}$ (e.g. $I_{cnv\_L} = 0.95 * I_{tgt\_cnv}$), whereas the high current limit I_{cnv_H} is typically set to a value that is equal to or slightly higher than the power converter target current I_{tgt_cnv} (e.g. $I_{cnv\_H} = I_{tgt\_cnv}$ or $I_{cnv\_H} = 1.05 * I_{tgt\_cnv}$). The operation of the control loop is known in the art, but an overview of the operation will be provided later in this text. Typically, when applying the duty cycle based control signal 132 to provide light output at the desired light intensity, the power converter target current I_{tgt_cnv} is kept constant or essentially constant and the duty cycle D_{req} is adjusted in accordance with any variations in the requested light intensity level received in the input control signal 115. Moreover, when the duty cycle based control is applied, the power converter target current I_{tgt_cnv} is typically set to the nominal output current of the driver 120, e.g. to the maximum output current I_{max} of the driver 120. The role of the power converter target current I_{tgt_cnv} is described in more detail in the following.

[0032] The power converter portion 140 may be provided as a switched-mode converter configured to convert the operating power 117 provided as input thereto at a first voltage into respective power converter output current in accordance with the control signals 132 and possible further control signal(s) received from the control portion 130. Moreover, the control portion 130 is further arranged to control generation of the driving current 125 on basis of the power converter output current. A switched-mode power converter may be embodied as a buck converter or another suitable converter for converting a first DC voltage into a second DC voltage according to desired voltage conversion characteristics. Such power converters are known in the art. The power converter portion 140 is configured to provide, when enabled, the output current at constant or essentially constant current following or approximating the power converter target current I_{tgt_cnv}.

[0033] To provide a more detailed example in this regard, Figure 4 schematically illustrates a buck converter arranged to provide the driving current 125 for the LED array 170. This exemplifying buck converter receives the operating power (117) via an input V_{in} and comprises a switch S, a diode D, an inductor L and a capacitor C. A driving circuit (or a driving portion) DRV is arranged to operate, i.e. to periodically open and close at a frequency significantly higher than the cycle frequency f_c, 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 LED array 170. A brief overview of operation of the control loop applied to operate switch S during an active period of the duty cycle based control signal 132, is provided in the following. During active periods of the duty cycle based control signal 132, the control loop of the power converter portion may cause operating the switch S such that in the beginning of an active period the switch S is closed. Consequently, the output current from the buck converter (from the inductor L) starts to increase. The switch S is kept closed until the output current reaches the high current limit I_{cnv_H}. In response to the output current reaching the high current limit I_{cnv_H}, the switch S is opened. Consequently, the output current starts to decrease. In response to the output current reaching the low current limit I_{cnv_L}, the switch S is closed again and the output current starts to increase towards the high current limit I_{cnv_H}. This sequence of closing and opening the switch S is repeated until termination of the active period. Consequently, the output current during the active period oscillates between the high current limit I_{cnv_H} and the low current limit I_{cnv_L}, and the average output current during the active period approximates the power converter target current I_{tgt_cnv}. The capacitor C connected in parallel with the LED array 170 serves to smooth the oscillation of the output current, thereby resulting in constant or essentially constant driving current 125 to be provided to the LED array 170 during the active period of the driving current 125.

[0034] Conceptually, the driving circuit DRV may be considered as a component of the power converter portion 140. However, in an embodiment of the driver 120 the driving circuit DRV may be provided e.g. as a component of the power converter portion 140 or as a component of the driver 120 separate from the power converter portion 140 that is connected or coupled to the power converter portion 140. As a further example, the driving circuit DRV may be provided as a component or a sub-portion of the control portion 130. Suitable driving circuits DRV 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.

[0035] The duty cycle based control signal 132 may be provided as an input to the driving circuit DRV of the buck converter serving as the power converter portion 140, and the driving circuit DRV is configured to operate the switch S to provide the driving current 125 at or approximately at the power converter target current I_{tgt_cnv} during active periods of the duty cycle based control signal 132, while on the other hand, the driving circuit DRV is configured to keep the switch S open during non-active periods of the duty cycle based control signal 132, thereby providing the driving current 125 as zero current or current that is essentially zero. In other words, the duty cycle based control signal 132 causes the power converter portion 140 to cyclically enable and disable provision of the driving current 125 in accordance with the active and non-active periods of the duty cycle based control signal 132. Consequently, the driving current 125 exhibits alternating active and non-active periods following or at least approximating the duty cycle D_{req} and the cycle frequency f_c of the duty cycle based control signal 132. Moreover, also the phase of the driving current 125 follows that of the duty cycle based control signal 132, although the processing applied in the power converter portion 140 is likely to cause a (fixed) delay between the corresponding cycles (e.g. active periods) of the duty cycle based control signal 132 and the resulting driving current 125. Hence, during active periods the driving current 125 exhibits essentially constant current at or approximating the power converter target current I_{tgt_cnv}, whereas during non-active periods the driving current 125 typically exhibits zero current or current that is essentially zero, resulting in an average driving current 125 that approximates $I_{tgt\_drv} = D_{req} * I_{tgt\_cnv}$ (when considering a full cycle or a number of such cycles), corresponding to the requested light intensity level.

[0036] As an alternative approach, the driving circuit DRV may be configured to continuously operate the switch S to provide the buck converter output current at or approximately at the power converter target current I_{tgt_cnv}, whereas the duty cycle based control signal 132 is provided to control a second switch arranged between the power converter portion 140 and the output (current) of the driver 120. In such an approach the second switch is cyclically closed and opened in accordance with the active and non-active periods of the duty cycle based control signal 132. Consequently, the driving current 125 provided to the output of the driver 120 is similar to that of the previous example where the duty cycle based control signal 132 is applied to cyclically enable and disable the operation of the power converter portion 140, i.e. the driving current 125 exhibits alternating active and non-active periods following or at least approximating the duty cycle D_{req} and the cycle frequency f_c of the duty cycle based control signal 132 to provide the driving current 125 that approximates $I_{tgt\_drv} = D_{req} * I_{tgt\_cnv}$.

[0037] As pointed out hereinbefore, the alternating active and non-active periods of the driving current 125 that are characteristic for the duty cycle based control may result in momentary non-active periods being perceived as flickering of light output by a human observer, especially at low duty cycles and/or low cycle frequencies. Moreover, momentary non-active periods of shorter duration and/or at higher frequency that may not be perceivable by a human observer may still cause a disturbing effect e.g. for digital imaging applications or machine vision applications.

[0038] In an arrangement involving multiple LED arrays 170 arranged to illuminate the same area/space of interest, such as the arrangement 100 of Figure 1, the perceived combined light output is the combination, e.g. sum, of the light outputs of the LED arrays 170. Consequently, any possible perceivable flickering of light results from the combined light output of the LED arrays 170. In a worst case scenario the duty cycle based control signals 132 of the drivers 120 employ the same cycle frequency f_c and the same duty cycle D_{req} such that the non-active periods of the cycle based control signals coincide in time, in other words the cycle based control signals 132 of the drivers 120 are in the same phase with respect to each other. A consequence of such a scenario is that during these non-active periods none of the LED arrays 170 is providing a light output and hence the flickering effect may be reinforced. In contrast, in a most favorable situation, assuming the same cycle frequencies f_c and the same duty cycles D_{req} across the drivers 120, phases of the duty cycle based control signals 132 are evenly distributed over cycle duration, thereby minimizing the flickering effect without affecting the perceived combined light output level. In general, setting or time-shifting the duty cycle based control signals 132 across the drivers 120 such that the periods during which none of the driving currents 125-i is in active state are made as short as possible serves to minimize the perceivable flickering of the light output without affecting the perceived combined light intensity.

[0039] Figures 5a and 5b, respectively, illustrate the above-mentioned 'worst case scenario' and 'optimal scenario' with respect to phase differences with two cycle based control signals 132. The curve (a) of Figure 5a indicates a first duty cycle based control signal 132 employing a first duty cycle $D_1 = t_{on1} / t_c$ and a cycle frequency f_c corresponding to cycle duration t_c and the curve (b) indicates a second duty cycle based control signal 132 employing a second duty cycle $D_2 = D_1$ (with $t_{on2} = t_{on1}$) at the cycle frequency f_c. The duty cycle based control signals of curves (a) and (b) are in the same phase, i.e. their active and non-active periods fully overlap in time. Since, as described hereinbefore, the driving current 125 follows the duty cycle, cycle frequency, and phase of the respective duty cycle based control signal 132, also the resulting light output levels from the respective LED arrays 170 change between 'high' and 'low' levels in accordance with the active and non-active periods of the duty cycle based control signals 132. In this example, assuming the light output from a single LED array 170 during an active period of the driving current 125 to be L_{out}, the combined light output from the LED arrays 170 exhibits corresponding active and non-active periods at cycle duration $t_{c\text{-sum}} = t_c$ with active periods having duration $t_{on\text{-sum}} = t_{on1}$, as illustrated by the curve (c). Moreover, the combined light output during active periods is the sum of the light levels from the individual LED arrays 170, i.e. $L_{out} + L_{out} = 2 * L_{out}$ and during non-active periods the combined light level is zero.

[0040] In Figure 5b the curve (d) indicates a first duty cycle based control signal 132 employing a first duty cycle $D_1 = t_{on1} / t_c$ and a cycle frequency f_c corresponding to cycle duration t_c and the curve (e) indicates a second duty cycle based control signal 132 employing a second duty cycle $D_2 = D_1$ (with $t_{on2} = t_{on1}$) at the cycle frequency f_c. The duty cycle based control signals of curves (d) and (e) are in the opposite phases, i.e. their active periods are spaced in time by $t_c / 2$ and hence there is no temporal overlap between the active periods of the first and second duty cycle based control signals of curves (d) and (e). The curve (f) indicates the combined light output from the LED arrays 170 resulting from the duty cycle based control signals 132 illustrated in the curves (d) and (e). As the curve (f) indicates, the time offset of $t_c / 2$ in the two exemplifying duty cycle based control signals 132 hence results in the cycle duration $t_{c\text{-sum}} = t_c / 2$, implying the cycle frequency $f_{sum} = 2 * f_c$, while the durations of the active periods are not changed but remain at t_{on1}. On the other hand, since there is no temporal overlap between the duty cycle based control signals 132, the combined light output during active periods of the output currents 125 remain at L_{out}. However, since the active periods on the curve (f) occur twice as frequently as in the curve (c), the resulting average (perceivable) combined light output is the same in both cases. Hence, in comparison to the curve (c), the periods during which none of the LED arrays 170 are providing light output are made shorter but more frequent. Consequently, any remaining flicker in the resultant combined light output from the LED arrays 170 is at a higher frequency.

[0041] While the above examples illustrate the effect of the relative phases of the driving currents 125-i by indicating the difference between the extreme scenarios of completely in-phase driving currents 125 and evenly distributed phases between the driving currents 125, phase distribution different from the even one may be helpful in reducing perceivable flickering of the combined light output. Even if such a non-even distribution of the time offsets will not provide the optimal reduction in perceivable flickering of light, in any case it serves to alleviate or reduce the perceivable flickering in the combined light output in comparison to a scenario where the active periods of all or majority of the duty cycle based control signals overlap in time.

[0042] Assuming that the drivers 120 in the arrangement 100 of Figure 1 issue the respective duty cycle based control signals 132 independently of each other, it is generally not possible to apply any predetermined time offset (or phase offset) in the duty cycle based control signal 132 of a given driver 120-i in relation to the duty cycle based control signals 132 of the other driver(s) 120. However, as discussed hereinbefore, the perceivable flickering of light may be caused by non-active periods of the duty cycle based control signals 132 across the drivers 120 overlapping in time, either fully or in part. Consequently, introducing a time offset to the duty cycle based control signal 132 of the driver 120-i, and hence to the resulting driving current 125-i, in order to change its phase in relation to the other driving currents 125 would serve as a measure that attempts to reduce the temporal overlap between the non-active periods in the driving currents 125. In case the time offset is successful in bringing the phases of the driving currents 125 further away from each other, the introduction of the time offset contributes towards reduced perceivable flickering of the combined light output of the LED arrays 170. Since introduction of the time offset, at most, results on only a very short-term change in the average driving current 125-i, the average light output from the respective LED array 170-i and the combined average light output from the LED arrays 170 is kept essentially unchanged.

[0043] In this regard, the control portion 130 may be configured to modify characteristics of the control signal(s) issued therefrom by introducing a suitable time offset to the duty cycle based control signal 132 in response to an indication of observed flickering of light in the area/space served by the LED arrays 170. Suitable time offset may be a randomly selected time offset. As another example, the suitable time offset may be a fixed predetermined time offset that is individually selected and set for each driver 120 separately such that the time offsets for the drivers 120 applied in illumination of the same area/space of interest are selected/set to be different from each other. The selection/setting may be carried out e.g. upon installation or (re)configuration of the driver 120. Applying randomly selected time offset or a fixed predetermined time offset different from that of the other drivers 120 operating in the area/space contributes to avoid a situation where two or more of the drivers 120 apply the same or essentially similar time offsets, which is not likely to result in reduced flickering due to phase difference between the duty cycle based control signals 132 applied in these two or more drivers 120 remaining unchanged.

[0044] The applied time offset is, preferably, shorter than the cycle duration t_c. The time offset, random or a predetermined one, may be defined e.g. as a period of absolute time (e.g. milliseconds or microseconds, as a number of clock ticks of a synchronization signal (clock signal) available in the driver 120, etc.). As another example, the time offset may be defined e.g. as a fraction of the cycle duration t_c.

[0045] The time offset may be introduced to the duty cycle based control signal 132 e.g. by delaying the control signal by the amount of time corresponding to the time offset. Consequently, e.g. an active period or a non-active period of the duty cycle based control signal may be extended (in time) by the amount of time corresponding to the time offset. As another example, the time offset may be introduced by shortening an active period or a non-active period of the duty cycle based control signal 132. In these examples the duty cycle of the modified cycle of the duty cycle based control signal 132 is changed, while other cycles of the duty cycle based control 132 signal are not affected. Consequently, a very short term variation in the light level provided by the LED array 170 may be introduced. As a further example, the time offset may be introduced by modifying the duration of a cycle of the duty cycle based control signal 132 such that the duty cycle of the modified cycle remains unchanged. Hence, such modification may comprise extending or shortening (in time) both the active period and the non-active period of the cycle such that the ratio t_{on} / t_c of the modified cycle remains at the desired duty cycle D_{req}. Consequently, the light level provided by the LED array 170 is kept unchanged also during the modified cycle.

[0046] The desired time offset may be introduced as a single modification operation of the duty cycle based control signal 132. Alternatively, the desired time offset may be introduced as a series of smaller steps at predetermined (temporal) intervals, which smaller steps combine into the desired time offset.

[0047] In case the introduction of the time offset is not effective in removing or reducing the flicker to a sufficient extent, the control portion 130 may be configured to re-introduce the time-offset according to one or more predetermined rules. Hence, the control portion 130 may be configured to re-introduce the time offset (a random one or a predetermined one) in response to continued or re-issued indication of observed flickering of light in the area/space served by the LED arrays 170 despite an earlier introduction of the time offset. In this regard, the control portion 130 may be configured to apply a predetermined minimum waiting time since the most recent introduction of the time offset before re-evaluating the need for (re-)introduction of the time offset. The predetermined minimum waiting time may be a value selected e.g. from a range from a few tenths of a second or a few seconds. Along the lines described hereinbefore for the fixed predetermined time offset, the predetermined minimum waiting time is preferably selected (e.g. upon installation or (re)configuration of the driver 120) to be different from that of the other drivers 120 serving the area/space. As another example, instead of applying the predetermined minimum waiting time, the control portion may be configured to apply a waiting time that is randomly selected from a predefined range (e.g. from the above-mentioned range from a few tenths of a second to a few seconds).

[0048] Furthermore, the control portion 130 may be configured to apply a predetermined maximum number of re-introductions of the time offset. The maximum number may be e.g. any number selected from the range from five to ten. An underlying assumption for using the maximum number of re-introductions is that if several attempts for phase re-alignment among the drivers 120 do not appear to remove the flickering of light, the flickering condition is likely such that this technique is not able to solve it in full - and any continued attempts of phase re-alignment by introducing time offset to the duty cycle based control signal 132 are not likely to significantly improve the situation.

[0049] Instead of introducing the time offset(s), the control portion 130 may be configured to modify characteristics of the control signals issued therefrom such that the duty cycle based control is discontinued and linear control is applied instead. Herein, linear control refers to an approach where the level of the driving current 125 is set or adjusted to match the desired and a continuous driving current 125 is provided. Applying linear control may comprise employing the means for setting or adjusting the power converter target current I_{tgt_cnv} such that it corresponds to light level requested or indicated in the input control signal 115. This may involve, for example, using setting the high current limit I_{cnv_H} and the low current limit I_{cnv_L}, described hereinbefore, to values that result in the power converter portion 140 providing the output current at the desired level. Discontinuation of the duty cycle based control may comprise, for example, setting the duty cycle of the duty cycle based control signal 132 to D_{req} = 100 % in order to cause provision of the driving current 125 continuously in the 'high' state, i.e. a continuous driving current without non-active periods.

[0050] Consequently, the power converter portion 140 is caused to provide constant or essentially constant output current that approximates the power converter target current I_{tgt_cnv}, and the power converter output current is applied as the driving current 125. As an example, if a command received in the input control signal 115 implies a request for an average driving current 125 that is X % of the maximum output current I_{max} of the driver 120, the means for setting or adjusting the power converter target current may be configured to set the power converter target t current to $I_{tgt\_cnv} = X * I_{max}$. Since the average driving current 125-i is not changed, the average light output from the respective LED array 170-i and the combined average light output from the LED arrays 170 is kept essentially unchanged.

[0051] Switching to linear control instead of the duty cycle based control may have an effect on the color temperature of the resulting light output from the LED array 170 due to the LEDs being driven with a current lower than their nominal current. On the other hand, the linear control ensures that the light output from the LED array 170 does not contribute to perceivable flickering of light, which may be considered as a positive effect that outweighs the potential discomfort due to a potential change in color temperature, especially at low illumination levels.

[0052] The duty cycle based control and the linear control described hereinbefore may be jointly applied in an attempt to alleviate the perceivable flickering of light. As an example, the control portion 130 may be arranged, in response to an indication of observed flickering of light, first attempt to remove the flickering by introducing the time offset using the technique described hereinbefore. Moreover, the control portion 130 may be configured to switch to the linear control in case the time offset based flicker removal turns out unsuccessful, e.g. in response to having applied the maximum number of re-introductions of the time offset without successfully removing the flickering condition.

[0053] As another example of joint application of the duty cycle based control and the linear control in flicker removal, the control portion 130 may be configured to apply the duty cycle based control and to apply the time offset introduction technique when the requested light intensity (and/or the requested average driving current 125) is above a predetermined threshold, and to apply the linear control when the requested light intensity is lower than or equal to said threshold. The threshold serving as the decision point may be based on experimental data that is characteristics of the employed configuration/installation of LED arrays 170 in order to find the lowest light intensity level where the duty cycle based control is still typically able to provide combined light output that does not involve perceivable flickering of light.

[0054] The control portion 130 may be configured to carry out flicker detection, e.g. to determine absence or presence of flickering, on basis of the sensor signal 113 and to issue (within the control portion 130) the indication of observed flickering of light in response to determining presence of flickering. The flicker detection may be carried out by a dedicated flicker detection portion within the driver 120. As described hereinbefore, the flickering of light is typically caused by periodic or essentially periodic sequence(s) of non-active periods in light output of the LED arrays 170 due to duty cycle based control. Since the sensor signal 113 reflects the combined light output from the LED arrays 170, the non-active periods in the light output of the LED arrays 170 contribute to momentary sub-periods of decreased light level that are captured in the sensor signal 113. The control portion 130 may be arranged to apply a flicker detection technique known in the art The flicker detection may comprise identifying one or more periodic or essentially periodic sequences of momentary sub-periods of decreased light level in the sensor signal 113 and determining flickering of light to be present in response to these identified sequence(s) exhibiting a frequency that is below a predefined threshold (e.g. 500 Hz), in other words in response to the identified sequence(s) exhibiting a period that is longer than a predefined threshold (e.g. 2 milliseconds).

[0055] A momentary sub-period that contributes to perceivable flickering may be a sub-period during which the observed light level is continuously lower than a predefined threshold at least for a predetermined period of time - in other words a sub-period of absolute value of the observed light level falling below the threshold. As another example, additionally or alternatively, a momentary sub-period that contributes to perceivable flickering may be a sub-period during which the difference between a reference light level and the observed light level is continuously larger than a predefined threshold for at least the predetermined period of time - in other words a sub-period wherein the light level is decreased more than indicated by the predefined threshold. The reference light level may be, for example, the instantaneous light level immediately preceding the sub-period, the maximum light level within a suitable time window (of e.g. a few seconds) preceding the sub-period, or the average light level within the time window.

[0056] Figure 6 schematically illustrates a lighting arrangement 100' that is a variation of the arrangement 100. The difference to the arrangement 100 is that the level adjustment portion 112 is located in the driver 120', as schematically illustrated in Figure 7. Therefore, there is no need for a sensor portion 110' to provide the input control signal 115 to the driver 120' but only the sensor signal 113 is provided. The level adjustment portion 112 is configured to determine and issue the input control signal 115 to the control portion 130, as described hereinbefore in context of the arrangement 100, in other words the input control signal 115 is issued within the driver 120'.

[0057] Figure 8 schematically illustrates some components of a sensor portion 110" and a driver 120". The sensor portion 110" is a variation of the sensor portion 110 and the driver 120" is a variation of the driver 120, both described in detail hereinbefore. The structure and operation of the sensor portion 110" are similar to those of the sensor portion 110, with the exception of inclusion of a flicker detection portion 114 in the sensor portion 110". The flicker detection portion 114 is arranged to receive the sensor signal 111 from the light sensor(s) 111. The flicker detection portion 114 is further arranged to determine absence or presence of flickering on basis of the sensor signal 113 and to issue a flicker indication 116 as an indication of observed flickering of light in response to determining presence of flickering.

[0058] The structure and operation of the driver 120" are similar to those of the driver 120 with the exception that instead of receiving the sensor signal 113 the driver 120" is configured to receive the flicker indication 116 from the sensor portion 110". Consequently, there is no need for flicker detection related processing in the driver 120". While the flicker indication 116 is depicted in Figure 8 as a signal separate from the input control signal 115, the flicker indication 116 may be carried as a command, request or indication in the input control signal 115.

[0059] Although described and depicted as a variant of the driver 120, the driver 120" may be equally well provided as a variant of the driver 120', where the level adjustment portion 112 is included in the driver 120" instead of the sensor portion 110" (and, consequently, the input control signal 115 becomes a signal within the driver 120" while the sensor signal 113 is provided from the sensor portion 110" to the driver 120".

[0060] The flicker detection portion 114 may carry the flicker detection as described hereinbefore in context of the driver 120.The flicker detection portion 114 may be configured to carry out the flicker detection along the lines outlined hereinbefore and/or in accordance with a flicker detection technique known in the art. The flicker detection portion 114 may be provided as a dedicated entity connected or coupled to the sensor portion 111 and to the driver 120" instead of being provided as a component of the control portion 130 (as in the drivers 120, 120') or as a component of the sensor portion 110".

[0061] Figure 9 schematically illustrates some components of an exemplifying arrangement 200 for providing light at a selectable light level. The arrangement 200 comprises a controller entity 210 for issuing input control signals 215-1, 215-2, ..., 215-n indicating desired characteristics of output currents to respective drivers 220-1, 220-2, ..., 220-n. The main difference to the arrangement 100 is the joint but selective control of the drivers 220 such that the controller entity 210 provides dedicated input control signal 115 to each of the drivers 220 in consideration of the input control signals 115 issued to the other drivers 220.

[0062] In Figure 9 the input control signals 115-i are provided via a shared signal line, which may be provided e.g. as a communication bus that may be employed to connect or couple the drivers 220 and possible further components to the controller entity 210. The communication bus may be provided as a DALI bus or a communication bus in accordance with another communication standard that is applicable for lighting control. Alternatively, instead of applying the communication bus, the input control signals 115-i may be provided as separate signals in their dedicated signals lines.

[0063] The drivers 220 are arranged to derive respective driving currents 125-i for the LED arrays 170 on basis of operating power 117 provided thereto in accordance with the characteristics of the respective input control signal 215-i received from the controller entity 210. As in case of the arrangement 100, the number n indicating the number of LED arrays 170 and hence the number of drivers 220 in the arrangement 200 may be any number greater than or equal to two.

[0064] The controller entity 210 may be arranged to issue input control signals to request the driver 220-i to control the respective LED array 170-i to provide a certain light intensity from the driver in response to a user input via a user interface and/or in response to a further control signal received at the controller entity 210 from a further entity. The controller entity 210 may further comprise or be connected or coupled to e.g. a PIR sensor arranged to provide sensor measurements and hence the controller entity 110 may be arranged to control issuance of the input control signals 115 in accordance with the sensor measurements.

[0065] Figure 10 schematically illustrates some components of the driver 220. The driver 220 is similar to the driver 120 in operation and structure with the exception that the driver 220 only receives the input control signal 115 (but not the sensor signal 113 or the flicker indication 116) and the control logic related to the introduction of time offset(s) to the duty cycle based control signal 132 and/or application of the linear control instead of (or in parallel with) the duty cycle based control is located in the controller entity 210 instead of the control portion 130.

[0066] In particular, the controller entity 210 may be configured to issue input control signals 115-i to provide each of the drivers 220-i with a dedicated time offset to be applied in response to a subsequent synchronization command to be issued by the controller entity 210 (e.g. as a command provided in the input control signal 115). The controller entity 210 may be configured to provide the time offsets and the synchronization command to the drivers 220 in response to activation of the arrangement 200 and/or the controller entity 210, e.g. in response to a user action causing the lights to be switched on. In such an arrangement any potential flickering of light due to ill-matching phases of the driving currents 125 is reduced or eliminated in a pre-emptive manner.

[0067] As an example, the driver 220 may be arranged to apply the indicated time offset by delaying the duty cycle based control signal 132 issued therein by the amount corresponding to the time offset (i.e. to change the current phase of the duty cycle based control signal 132 by the amount defined by the time offset). As another example, the driver 220 may be arranged to commence provision of the duty cycle based control signal 132 after a delay defined by the time offset upon reception of the synchronization command.

[0068] In a variation of the arrangement 200 the controller entity 210 may be further arranged to receive the sensor signal 113 from the sensor portion 110'. Moreover, the controller entity 210 may further comprise the flicker detection portion 114 described hereinbefore arranged to provide the flicker indication 116 (within the controller entity 210) in response to detecting presence of flickering of light. Alternatively, the flicker detection portion 114 may be provided outside the controller entity 210, e.g. as a component of the sensor portion 110'. In such an arrangement the controller entity 210 may be configured to receive the flicker indication 116 instead of the sensor signal 113.

[0069] In the flicker-detecting variant(s) of the arrangement 200 the controller entity 210 may be arranged to provide the time offsets to the drivers 220 upon activation of the controller entity 220 (as described hereinbefore), while the controller entity 220 may be configured to issue the synchronization command that instructs all drivers 220 to apply the time offset provided thereto earlier in response to the indication of observed flickering of light.

[0070] The dedicated time offsets for the drivers 220 are preferably selected such that an even distribution of phases over the cycle duration t_c is provided across the driving currents 125. As another example, randomly selected time offsets may be applied, along the lines described hereinbefore in context of the driver 120.

[0071] Instead of applying the time offsets, the controller entity 210 in the flicker-detecting variant(s) of the arrangement 200 may be configured to issue, in response to the indication of observed flickering of light, input control signals 115-i that instruct the respective drivers 220-i to discontinue the duty cycle based control and to adjust or set the power converter target current I_{tgt_cnv} such that it corresponds to requested light level (also) indicated to the driver 220-i. The transition from the duty cycle based control to the linear control may be provided in a manner similar to that described hereinbefore for the control portion 130 of the driver 120, with the exception that the control signals instructing to carry out the transition are received in the driver 220 from the controller entity 210 (instead of the control portion 130 of the respective driver making the decision regarding the transition). Moreover, as a further example, the controller entity 210 may be arranged to instruct or control the drivers 220 to jointly apply the duty cycle based control and the linear control along the lines described for the driver 120 (with the difference of the control portion 130 controlling the selection of the applied control approach).

[0072] The operations, procedures and/or functions described in context of the arrangements 100 and 200 (and their variants) may be provided as steps of a method. As an example in this regard, Figure 11 illustrates a flowchart descriptive of a method 400 for providing the driving current 125 at a requested average level to the LED array 170 using the driver 120. The method 400 comprises providing the duty cycle based control signal 132 to cause cyclically enabling and disabling provision of the driving current 125 from the driver 120 such that the average of the driving current 125 at the output of the driver 120 corresponds to the requested light level, as indicated in block 410. In case an indication of observed flickering of light in a location within the area/space served by the LED array 170 is received (block 420), the method 400 proceeds to introducing a time offset to the duty cycle based control signal 132 (e.g. as described in the foregoing) in order to reduce or completely eliminate perceivable flickering of light, as indicated in block 430. Such modification of characteristics of the driving current 125 contributes towards eliminating perceivable flickering of light while the average of the driving current 125 continues to correspond to the requested light level. In case no flickering of light is indicated, the duty cycle.

[0073] In one variation of the method 400 the modification of the characteristics of the driving current 125 (block 430) comprises enabling continuous provision of the driving current 125 from the driver 120 while decreasing the power converter target current I_{tgt_cnv} such that continuously provided driving current 125 corresponds to the requested light level (in other words, corresponds to the average of the duty cycle controlled driving current 125). Further variations to the method 400 may be applied e.g. in view of the description of the driver 120 provided in the foregoing.

[0074] The control portion 130 of the driver 120, 120', 120", 220 may be provided by hardware means, by software means, or by combination of hardware and software means. As a particular example, the control portion 130 may be provided as one or more integrated circuits (IC) or as one or more processors carrying out instructions stored in a memory, which instructions control provision of the control signal 132 and possible further control signal(s) as described hereinbefore. The IC(s) or the processor(s) may be provided with output lines (e.g. output pins) via which the duty cycle based control signal 132and possible further control signal(s) are provided. As another example, the control portion 130 may be provided as an electronic circuit (composed of individual electronic components) that is arranged to control provision of the control signal 132 and possible further control signal(s) as described hereinbefore. As a further example, the control portion 130 may be provided as a combination of an electronic circuit, one or more IC and/or one or more processors, the electronic circuit, ICs and/or the processors jointly arranged to control provision of the control signal 132 and possible further control signal(s) as described hereinbefore.

[0075] Figure 12 schematically illustrates some components of an exemplifying apparatus 300 upon which the control portion 130 of the driver 120, 120', 120", 220 may be implemented. The apparatus 300 comprises a processor 310 and a memory 320, the processor 310 being configured to read from and write to the memory 320. The apparatus 300 may further comprise further structural units or portions, such as a communication interface 330 that may provide the (wireless or wireline) connection to the sensor portion 110, 110', 110", the connection(s) to the controller entity 210 and/or connections within the driver 120, 120', 120", 220 (e.g. between the control portion 130 and the power converter portion 140). Although the processor 310 is illustrated as a single component, the processor 310 may be implemented as one or more separate components. Although the memory 320 is illustrated as a single component, the memory 320 may be implemented as one or more separate components.

[0076] The memory 320 may store a computer program 350 comprising computer-executable instructions that control the operation of the apparatus 300 when loaded into the processor 310 and executed by the processor 310. As an example, the computer program 350 may include one or more sequences of one or more instructions. The computer program 350 may be provided as a computer program code. The processor 310 is able to load and execute the computer program 350 by reading the one or more sequences of one or more instructions included therein from the memory 320. The one or more sequences of one or more instructions may be configured to, when executed by one or more processors, cause the apparatus 300 to implement the operations, procedures and/or functions described hereinbefore in context of the control portion 130.

[0077] Hence, the apparatus 300 may comprise at least one processor 310 and at least one memory 320 including computer program code for one or more programs, the at least one memory 320 and the computer program code configured to, with the at least one processor 310, cause the apparatus 300 to perform the operations, procedures and/or functions described hereinbefore in context of the control portion 130.

[0078] The computer program 350 may be provided at the apparatus 300 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 the apparatus 300 cause the apparatus 300 at least to carry out operations, procedures and/or functions described hereinbefore in context of the control portion 130. 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 Blue-Ray disc or another article of manufacture that tangibly embodies the computer program 350. As a further example, the delivery mechanism may be a signal configured to reliably transfer the computer program 350.

[0079] Reference(s) 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. A driver apparatus for providing a driving current to one or more light emitting diodes, LEDs, the driver apparatus comprising
a power source portion for providing the driving current, the power source portion arranged to provide, when enabled, the driving current at a first level, and
a control portion for controlling the provision of the driving current to provide light output at a requested light level, the control portion configured to issue one or more control signals comprising a duty cycle based control signal to cause cyclically enabling and disabling provision of the driving current such that the average driving current corresponds to said requested light level,
wherein the control portion is configured to modify characteristics of the driving current, in response to an indication of observed flickering of light in a location served by said one or more LEDs, such that the average driving current continues to correspond to said requested light level.

2. A driver apparatus according to claim 1, wherein said duty cycle based control signal comprises a pulse-width modulation, PWM, signal.

3. A driver apparatus according to claim 1 or 2, wherein the control portion is configured to modify the characteristics by introducing a time offset to said duty cycle based control signal in response to said indication of observed flickering of light.

4. A driver apparatus according to claim 3, wherein said time offset is a randomly selected fraction of the cycle duration of the duty cycle based control signal.

5. A driver apparatus according to claim 1 or 2, wherein the control portion is configured to modify the characteristics by enabling continuous provision of the driving current and decreasing the first level such that the average of continuously provided driving current corresponds to the average of the duty cycle controlled driving current.

6. An apparatus according to claim 5, wherein enabling continuous provision of the driving current comprises setting the duty cycle of the duty cycle based control signal to 100 %.

7. A driver apparatus according to any of claims 1 to 6, further comprising a flicker detection portion arranged to
determine absence or presence of flickering on basis of a sensor signal indicative of the observed light level in the location served by said one or more LEDs, and
issue the indication of observed flickering of light in response to determining presence of flickering.

8. A driver apparatus according to claim 7, wherein the flickering detection portion is configured to determine presence of flickering in response to identifying, in the sensor signal, a periodic or essentially periodic sequence of momentary sub-periods of decreased light level exhibiting a period that is longer than a predefined threshold.

9. A driver apparatus according to claim 8, wherein a momentary sub-period of decreased light level comprises a sub-period wherein
the difference between the light level immediately preceding the sub-period and the observed light level

during the sub-period continuously exceeds a first predetermined threshold at least for a predetermined period of time, and/or
the observed light level is continuously lower than or equal to a second predetermined threshold at least for said predetermined period of time.

10. A lighting arrangement comprising
two or more driver apparatuses according to any of claims 1 to 7, and
a flicker detection portion arranged to
determine absence or presence of flickering on basis of a sensor signal indicative of the observed light level in the location served by said one or more LEDs, and
provide the indication of observed flickering of light to said two or more driver apparatuses in response to determining presence of flickering.

11. A method for providing a driving current to one or more light emitting diodes, LEDs, by using a driver apparatus comprising a power source portion for providing the driving current, the power source portion arranged to provide the driving current at a first level, the method comprising issuing one or more control signals for controlling the provision of the driving current to provide light output at a requested light level, said control signals comprising a duty cycle based control signal to cause cyclically enabling and disabling provision of the driving current such that the average of the driving current corresponds to said requested light level, and modifying characteristics of the driving current, in response to an indication of observed flickering of light in a location served by said one or more LEDs, such that the average driving current continues to correspond to said requested light level.

12. A method according to claim 11, wherein said modifying comprises modifying the characteristics by introducing a time offset to said duty cycle based control signal in response to said indication of observed flickering of light.

13. A method according to claim 11, wherein said modifying comprises modifying the characteristics by enabling continuous provision of the driving current and decreasing the first level such that the average of continuously provided driving current corresponds to the average of the duty cycle controlled driving current.

14. A computer program for providing a driving current to one or more light emitting diodes, LEDs by using a driver apparatus comprising a power source portion for providing the driving current, the computer program including one or more sequences of one or more instructions which, when executed by one or more processors, cause the driver apparatus to at least perform the method according to any of claims 11 to 13.

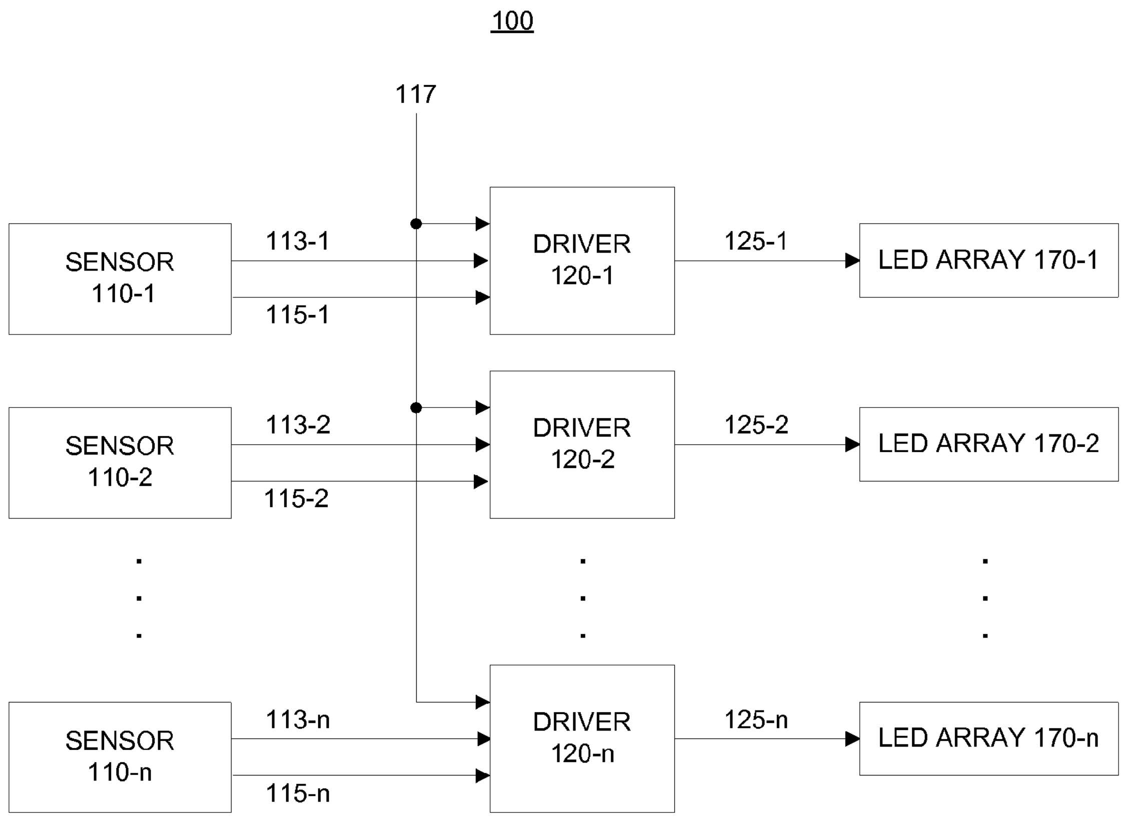


Figure 1

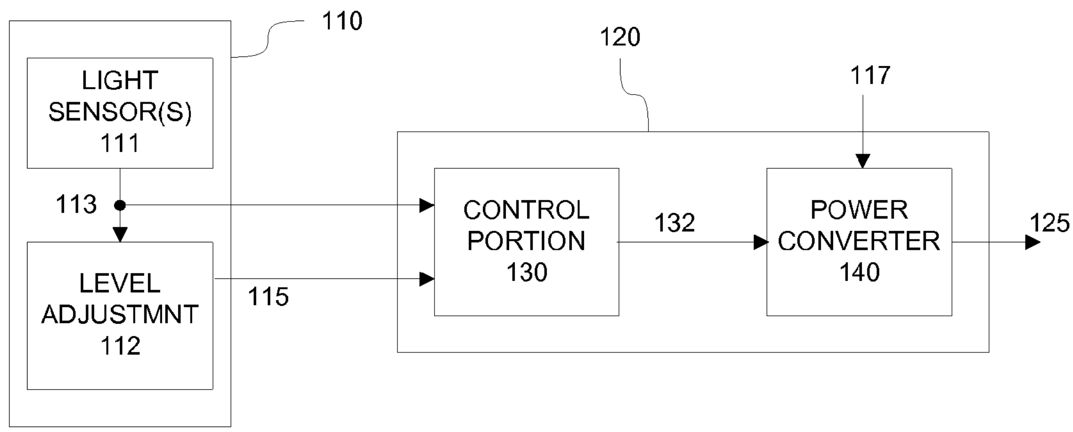
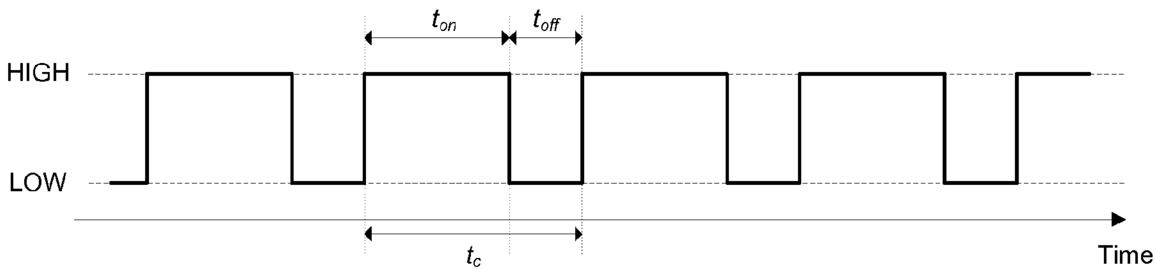


Figure 2



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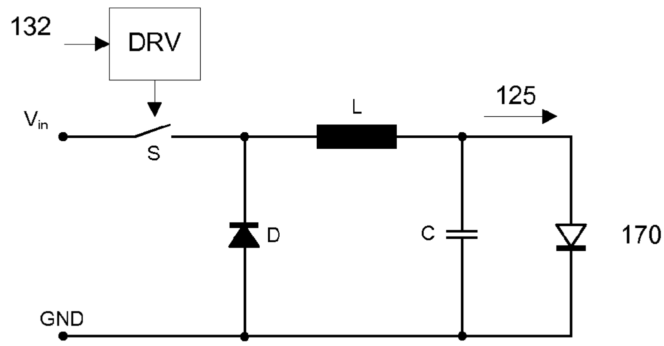

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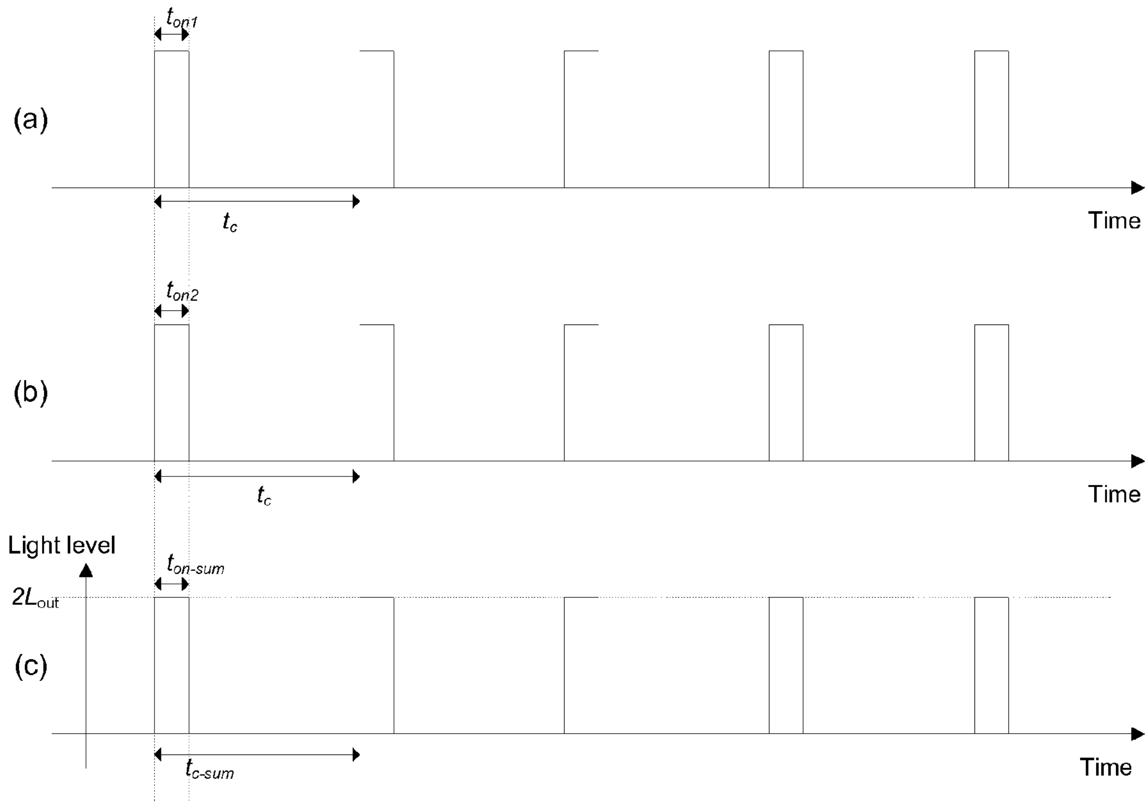

Figure 5a

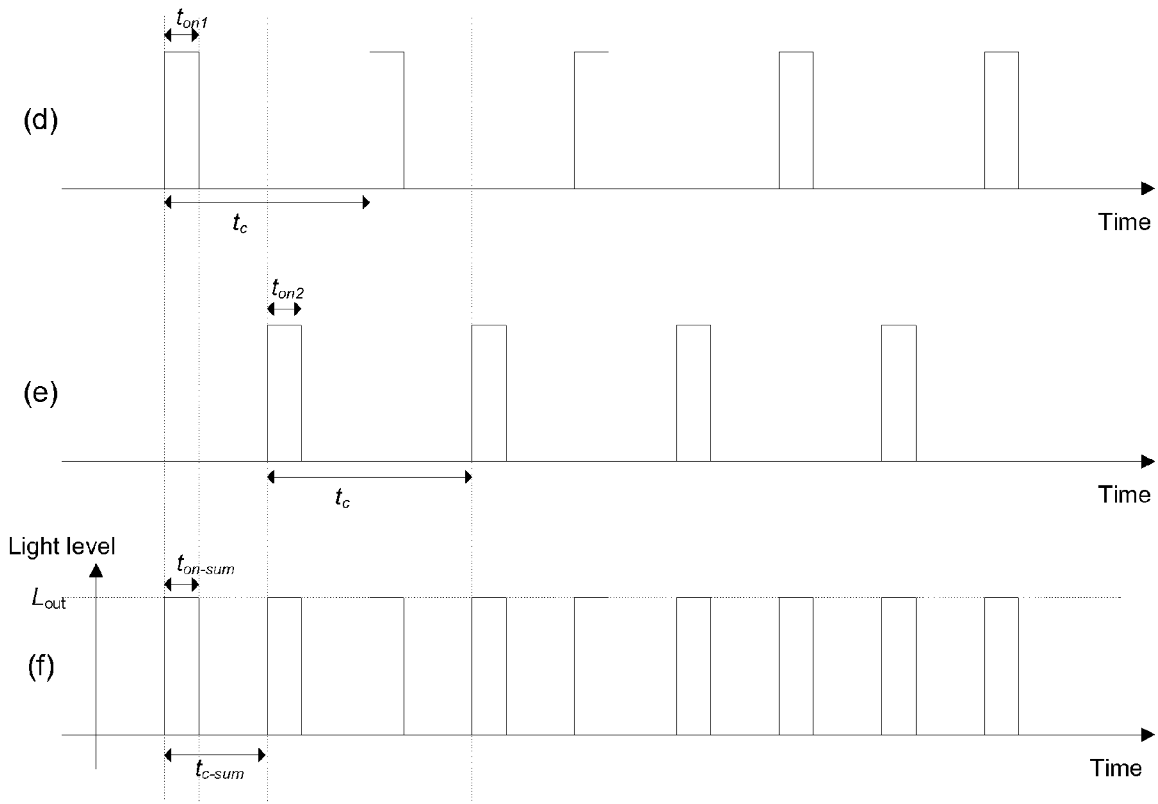

Figure 5b

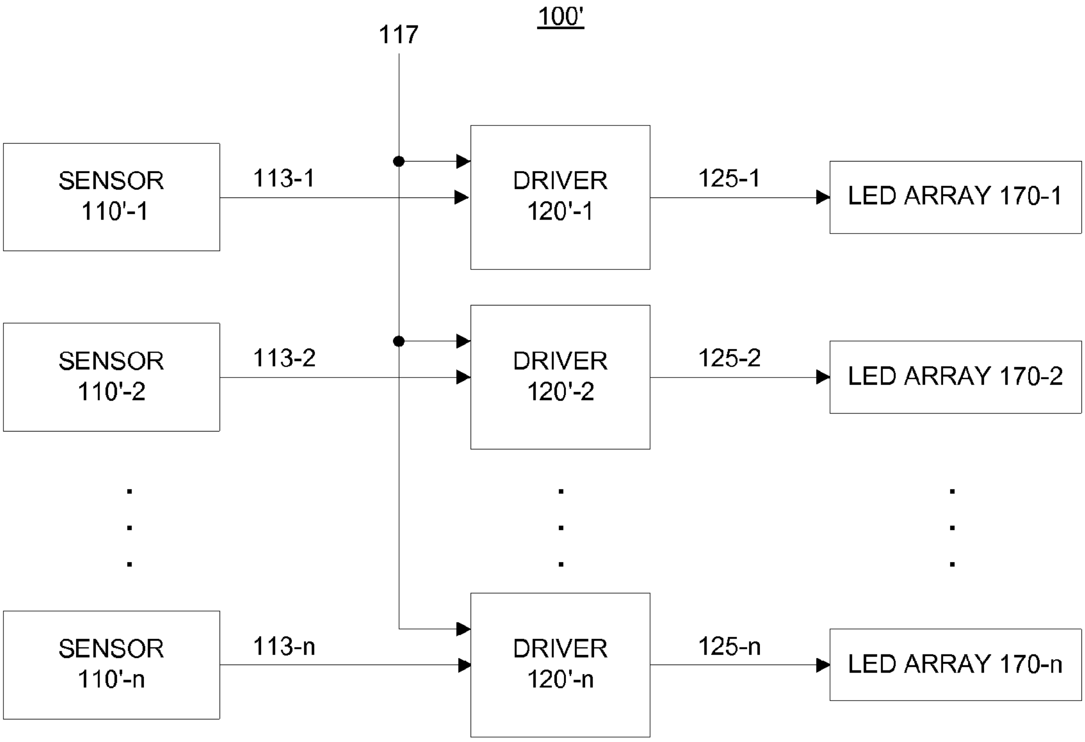

Figure 6

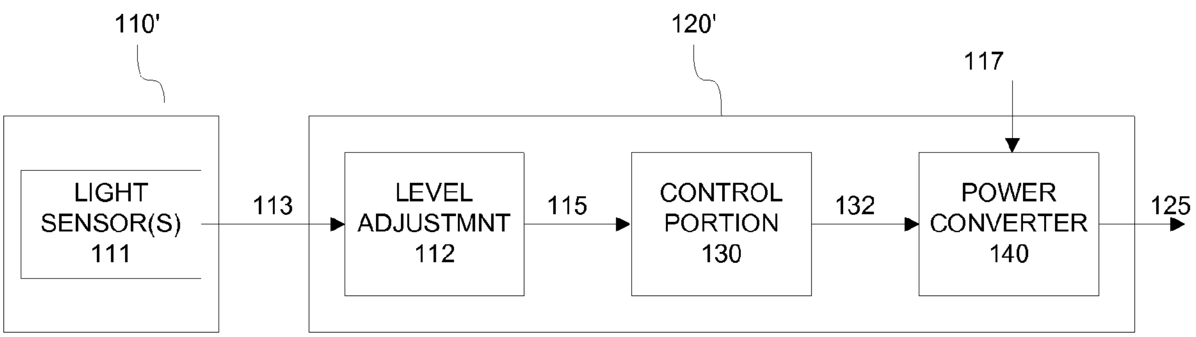

Figure 7

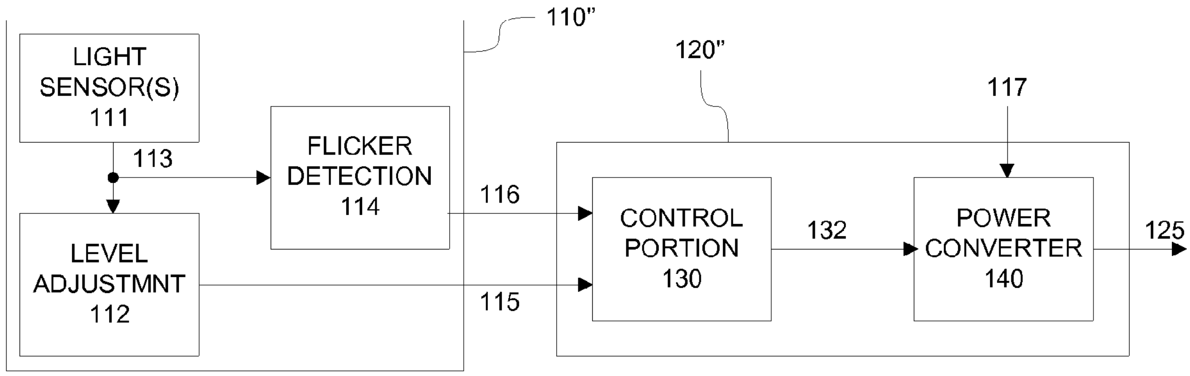

Figure 8

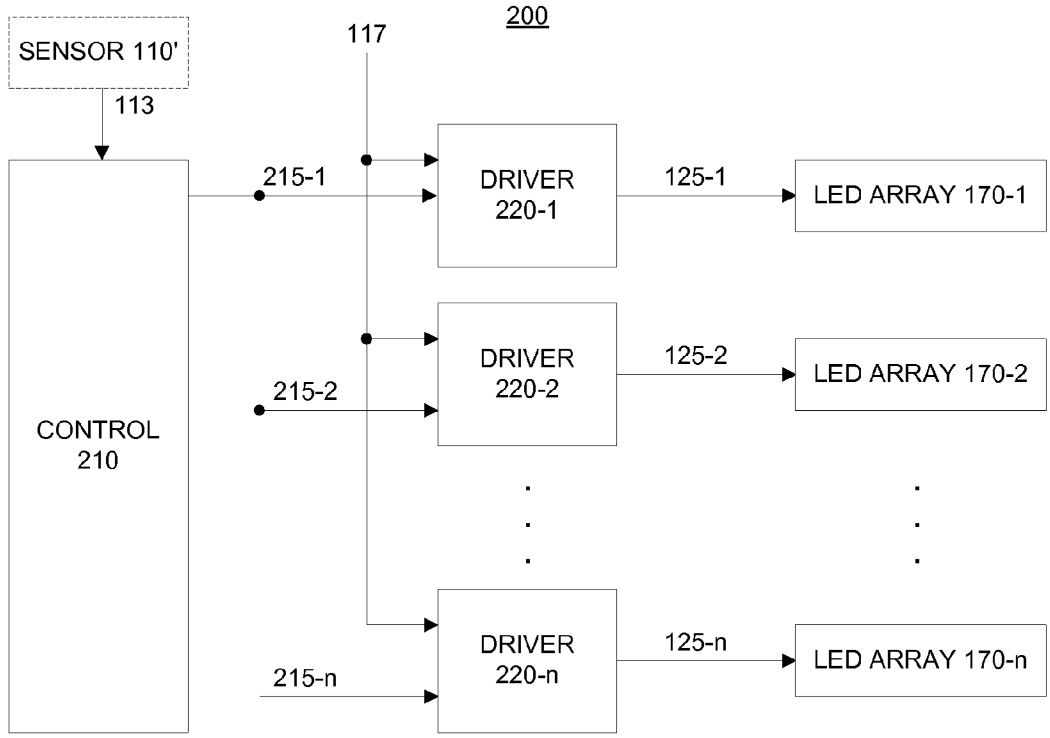

Figure 9

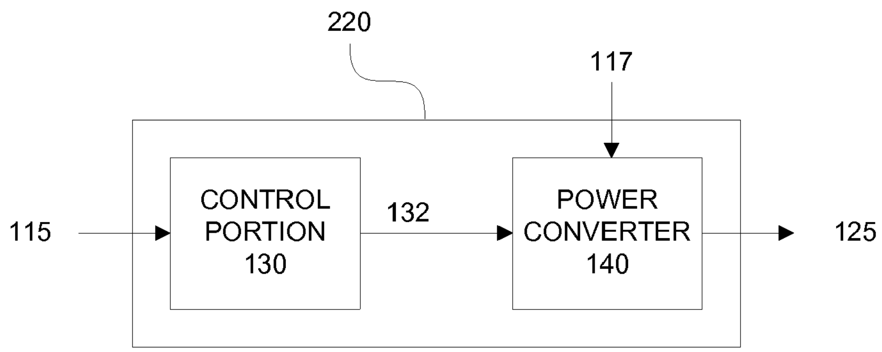

Figure 10

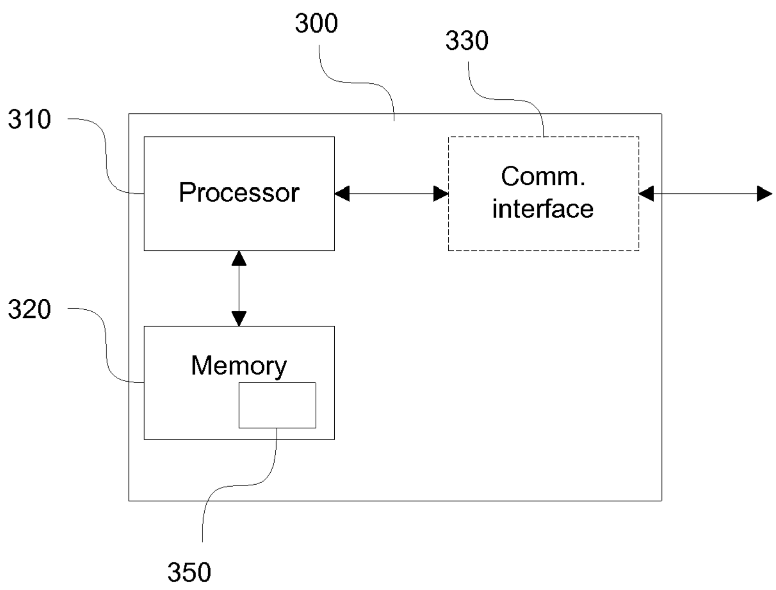

Figure 12

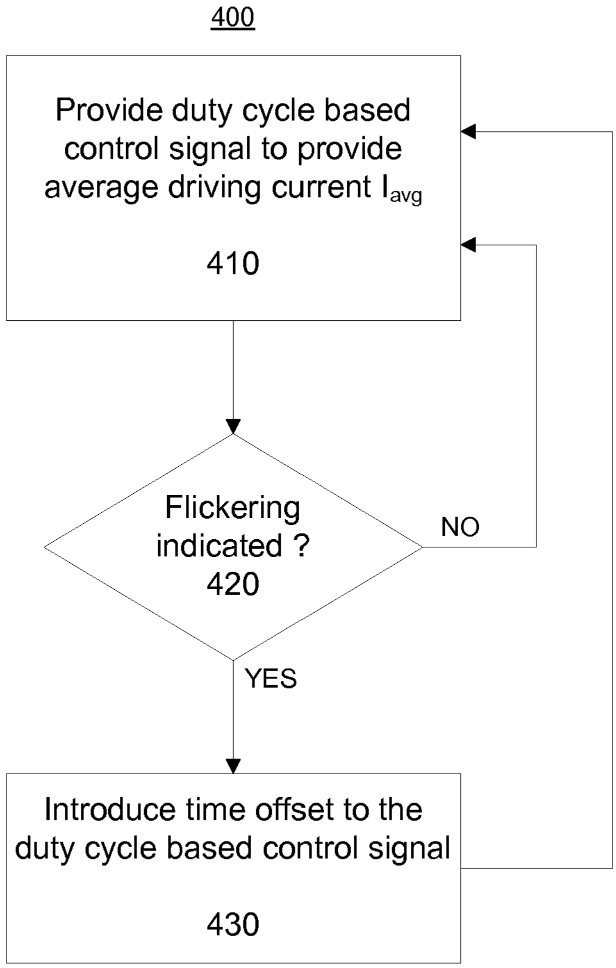
400
Provide duty cycle based control signal to provide average driving current I avg
410
Flickering indicated ?
420
NO
YES
Introduce time offset to the duty cycle based control signal
430

Figure 11

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EUROPEAN SEARCH REPORT

Application Number
EP 14 15 3250

DOCUMENTS CONSIDERED TO BE RELEVANT

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H05B

1

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	22 July 2014	Villafuerte Abrego

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22-07-2014

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