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(54) **LED driver and a method in connection with a LED driver**

LED-Treiber und Verfahren in Verbindung mit einem LED-Treiber

Circuit de commande de DEL et procédé associé à une commande de DEL

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Description

FIELD OF THE INVENTION

[0001] The present invention relates to producing illumination with LEDs, and particularly to using a pulse width modulated LED driver for producing controlled illumination.

BACKGROUND OF THE INVENTION

[0002] Illumination using LEDs (Light Emitting Diodes) is gaining popularity due to improved properties of the LEDs. The brightness of the LEDs is controlled by controlling the current through the component. Thus the dimming of the illumination is carried out with current control. Current can be controlled in linear manner, that is using a driver that provides continuous current to the LEDs. However, it has been found out that as LEDs are dimmed with continuous current, the produced lightning may change its colour.

[0003] Another way of controlling the lighting level is to use a LED driver that employs pulse width modulation (PWM). In pulse width modulation the current is controlled by changing the duty cycle of the PWM signal. During the On-period of the PWM signal the current has a constant value, which is typically the nominal value of the LED current. The average value or the effective value of the current is directly proportional to the duty cycle of the PWM signal. With PWM the LED lighting is dimmed by extending the time of Off-periods in PWM switching periods. Also more elaborate PWM schemes exist in which the PWM switching period does not consist of just simple On- and Off-periods but may comprise periods of various non-zero current levels.

[0004] When the current of a LED is controlled using PWM the PWM frequency should be selected to be so high that the human eye is not able to notice the Off-periods of the PWM signal. During the Off-periods current is not flowing through the LEDs and if these periods are made too long, the light seems to flicker which tends to have an irritating effect. Similar considerations apply to the more elaborate PWM schemes mentioned above, where the changes in current level may become visible if they are too long. Flicker may also become visible in an indirect way, in the form of the so-called stroboscopic effect of moving objects. Further disadvantageous consequences of flicker include for example the possible interference with the scanning frequencies of digital imaging devices.

[0005] It is usually advisable to select the PWM frequency to be high so to avoid the problems relating to flicker and possible interference with other illumination sources. As it is known, the switching period of a PWM signal gets shorter as the PWM frequency gets higher. That is to say that for the same duty cycle the On- and Off- pulses in the switching period are shorter when the PWM frequency is higher. When the PWM LED driver is dimmed to 1 % of the maximum output, the width of the On-pulse is 1% of the switching period. For example, if the PWM frequency is 1kHz, the On-pulse corresponding to 1% duty cycle is 10 μs. The requirement for short and accurate pulses leads to increased component and design costs, and therefore unnecessarily high PWM frequencies should not be selected.

[0006] Document US 2012286686 A1 discloses a method in which the PWM frequency is changed either continuously or stepwise as a function of dimming ratio. In the document the PWM frequency is changed during the use of the PWM LED driver. The change of PWM frequency may lead to stability problems and problems during the dimming of the lighting. As the dimming information is changed, the change of PWM frequency may lead to non-linearity in the dimming.

[0007] Document US 6,724,158 B1 discloses a method and a circuit in which the dimming control signal changes both the PWM frequency and the PWM duty cycle simultaneously.

BRIEF DESCRIPTION OF THE INVENTION

[0008] An object of the present invention is thus to provide a method and an apparatus for implementing the method so as to solve the above problems. The objects of the invention are achieved by a method and an apparatus which are characterized by what is stated in the independent claims. Preferred embodiments of the invention are disclosed in the dependent claims.

[0009] The invention is based on the idea of selecting the PWM frequency used in the LED driver based on the maximal dimming level set in the illumination system. When a maximal dimming level is set by the user or by a lighting controller, the driver selects a PWM frequency that is used throughout the set dimming range.

[0010] An advantage of the invention is that as the PWM frequency is selected based on the maximal dimming or minimum current level, the PWM frequency can be selected such that long enough switching period is secured in the lower end of the dimming range while still keeping the PWM frequency in such a high value that the adverse effects of low PWM frequency are avoided.

[0011] With the method and the apparatus of the invention the construction of the driver can be kept simple as the PWM frequency is not changed during the actual dimming.

[0012] According to a preferred embodiment of the invention, the used PWM frequency is selected from a set of PWM frequencies depending on the set lowest dimming value. When the PWM frequencies that can be used in a driver are known, the frequencies can be taken into account in the design of the driver such that the driver operates efficiently in each selected PWM frequency.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] In the following the invention will be described

in greater detail by means of preferred embodiments with reference to the attached drawings, in which

Figure 1 shows a block diagram of a PWM driver driving a LED array; and

Figure 2 shows a flow chart of the method of the invention.

DETAILED DESCRIPTION OF THE INVENTION

[0014] Figure 1 shows a block diagram of a PWM driver 10 for supplying power to one or more LED light source 11 comprising one or more LED illumination elements.

[0015] The PWM driver 10 comprises typically an input stage having active switch components. The input stage used in the example of Figure 1 is an AC to DC converter 12 which produces DC voltage from an AC source. The AC source is typically mains voltage and thereby the PWM driver is connectable to utility network. The input stage may follow the topology of any known type of AC to DC converter, such as boost, flyback or buck converter. The input stage also comprises a power factor correction circuit which operates such that current is drawn from the utility network in an optimal phase with reference to the voltage of the utility network.

[0016] The PWM driver of Figure 1 comprises further an output converter 13 which produces controlled current to the output of the PWM driver. The output converter can produce constant current from the DC voltage produced by the input stage. An example of the output converter is a buck converter, which is a step-down type converter. The output converter is a switching converter which uses the DC voltage produced by the input stage to repeatedly make current through one or more inductive components increase and decrease, alternatingly storing and releasing energy, so that a DC output voltage of the PWM driver is achieved. A nominal current of LED illumination sources is given as a reference for the output converter, and the converter operates to produce the set current. As the output converter performs switching at high frequency, the output current to the illumination sources may have a small ripple. The ripple is, however, so small that it has no visible effect on the light output from the LED illumination sources.

[0017] If the output from the output converter of the LED driver would be continuously fed to the LED illumination sources, the lighting produced by the sources would be at its nominal value. In the invention, the output current is pulse width modulated. The pulse width modulation is applied such that during Off-periods of the PWM signal the current from the illumination sources is cut off and during the On-periods the current having a nominal value of the LED illumination sources is fed to the LED illumination sources. When the effective current to the illumination sources is controlled with PWM, the illumination from the LEDs is also controlled. The PWM control can be obtained by using an Enable input in the output converter. A converter, such as a buck converter, can be produced using commercially available circuits. A commercially available buck controller may have an input that enables the output of the circuit, i.e. allows the circuit to produce the switching pulses that are fed to the control electrode of a switch, such as the gate of a MOSFET. By controlling Enable input, the output of the converter circuit can be shut down for the Off-periods of the PWM signal.

[0018] Figure 2 shows a flow chart of the method of the invention. According to the method, a controlled current is provided to an output of the LED driver for providing controlled illumination from a LED light source 21. Further, a pulse width modulator having a PWM frequency is employed to produce the controlled current 22.

[0019] In certain illumination control systems the minimum level requested from the illumination is set prior to the actual use of the illumination. That is to say that the illumination system is preparatorily configured such that when a minimum illumination level is requested during use, the lighting is dimmed only to that set level. The set illumination level may be, for example a certain percentage of the full lighting. The user may configure the system that the minimum illumination level that will be used is for example 5% or 10 % of the full lighting. If such lower limit is not set, the dimming can go down to the lowest level of illumination that is technically possible to produce with a particular combination of driver and illumination sources.

[0020] In a programmable illumination system the step of setting the minimum level requested from the illumination may take place repeatedly. For example the illumination system of a theatre may be programmed to operate in accordance with the scenes and/or acts of the play, so that e.g. the minimum level requested from the illumination in one act differs from that requested in a subsequent act. In such case a controller of the illumination system may transmit a configuration command to all drivers in the illumination system at the end of the first act, instructing them to set a new minimum level before the next act begins.

[0021] In the LED driver of the invention the minimum value of the controlled current is set. The minimum value of the controlled current is associated with the maximal dimming of the LEDs. In connection with a PWM LED driver, the minimum value of the controlled current as percentage of the nominal current is also the minimum value of the duty cycle of the PWM signal. We may also assume an essentially linear relationship between effective current and level of illumination. Thus if an instruction is given to the LED driver that the maximal dimming is 10% of the nominal illumination, then the shortest duration of the On-pulses of the PWM signal is 10% of the pulse period. If the relationship is not linear, the LED driver may apply a correction table, a mapping function, or some corresponding means to select the appropriate shortest duration of the On-pulses corresponding to each desired value of maximal dimming.

[0022] The minimum value of the controlled current is obtained from a value that indicates desired maximal

dimming (or desired minimum illumination level), given by the user of the illumination system. This value is inputted as programming information typically when the illumination system is taken into use and/or programmed for scene sequences or other changes that should take place. The programming may be carried out using any known programming means. For example in lighting systems implementing DALI protocol (Digital Addressable Lighting Interface), the programming may be carried out using a programmer that sends information to the LED drivers using a control bus 14. The programming may also be carried out at a central controller, which then sends the configuration commands to the LED drivers according to a programmed timetable. In the LED driver, the maximal value of dimming i.e. minimum value of current is stored as a parameter.

[0023] According to the invention, the LED driver comprises means adapted to set the PWM frequency of the pulse width modulator on the basis of the minimum value of the controlled current. As mentioned above, when the minimum output current or lighting level is set, the minimum of the duty cycle of the PWM driver is also known. The PWM frequency is set such that if the minimum output current or lighting level is low, the used PWM frequency is also low to enable producing the On-pulses of even the lowest duty cycle still with a reasonable length. When, on the other hand, the set minimum lighting level is higher, a higher PWM frequency can be selected for the pulse width modulator, because even if this means a shorter switching period of the PWM signal, the shortest On-pulse that will be needed will still remain reasonably long.

[0024] With reference to Figure 2, the method comprises setting a minimum effective value of the controlled current 23, and setting the PWM frequency of the pulse width modulator on the basis of the set minimum effective value of the controlled current 24.

[0025] In the LED driver a microprocessor 15 receives a command indicative of a selected minimum lighting level. After receiving the command, the microprocessor selects a PWM frequency for the pulse width modulation. The frequency may be selected e.g. by using a stored calculational formula, but according to an embodiment of the invention it is selected among a relatively limited set of selectable PWM frequencies by consulting a look-up table, for instance. Such a look-up table consists of dimming limit values and corresponding PWM frequencies. Following Table 1 shows an example of such a look-up table.

TABLE 1

Maximal dimming	PWM frequency
1-4%	100 Hz
5-9%	200 Hz
10-14%	500 Hz
15-20%	800 Hz
> 20%	1000 Hz

[0026] In the example of Table 1 five different PWM frequencies are selectable based on the set value of maximal dimming. The table should be read such that when a value, for example, between 1% and 5% is selected as maximal dimming, the selected PWM frequency is 100Hz. It should be understood that the values in the above table are only examples. It is possible to have different number of PWM frequencies ranging from two to ten, for example. It is also possible to select the possible PWM frequencies such that the design of the inductive or filter components of the driver can be made effectively.

[0027] The implementation of pulse width modulation can be done using a microprocessor of the PWM driver. The microprocessor receives the maximal value of the dimming, and based on the maximal value selects the PWM frequency that is used during the operation of the PWM driver. The microprocessor generates the selected PWM frequency and based on the inputted dimming control changes the duty cycle of the pulse periods.

[0028] The microprocessor may also output the dimming information together with selected PWM frequency to a separate PWM circuit. The output of the PWM circuit is connected to an enable input of the output converter such that flow of current is enabled from the output converter only during the On-periods of the PWM signal.

[0029] As the output converter produces current having a value of nominal current, the pulse width modulated output current has an effective value that is directly proportional to the duty cycle.

[0030] It will be obvious to a person skilled in the art that, as the technology advances, the inventive concept can be implemented in various ways. The invention and its embodiments are not limited to the examples described above but may vary within the scope of the claims.

Claims

1. A LED driver (10) comprising
an output adapted to provide a controlled current for providing controlled illumination from a LED light source (11),
a pulse width modulator having a pulse width modulation frequency, hereinafter PWM frequency, and adapted to produce the controlled current,
characterized in that it comprises:

means (14, 15) adapted to set a minimum effective value of the controlled current correspond-

ing to a maximal dimming level of a dimming range,
means (14, 15) adapted to set the PWM frequency to be used throughout said dimming range on the basis of the set minimum effective value of the controlled current.

2. A LED driver (10) according to claim 1, wherein the LED driver (10) comprises an output converter (13) adapted to produce current having a constant nominal magnitude, wherein the pulse width modulator is adapted to pulse width modulate the current of the output converter (13) for producing the controlled current.

3. A LED driver (10) according to claim 2, wherein the output converter (13) is a buck converter having a higher switching frequency than the PWM frequency of the pulse width modulator.

4. A LED driver (10) according to claim 3, wherein the output of the pulse width modulator controls the buck converter (13) such that during On-periods of the pulse width modulated signal the output of the buck converter (13) is enabled.

5. A LED driver (10) according to any one of the previous claims 1 to 4, wherein the means (14. 15) adapted to set the minimum effective value of the controlled current comprises input means (14) for receiving maximal dimming information.

6. A LED driver (10) according to any one of the previous claims 1 to 5, wherein the means (14, 15) adapted to set the PWM frequency of the pulse width modulator comprise at least two pre-selected values of PWM frequencies that are selectable on the basis of the maximal dimming information.

7. A method in connection with a LED driver comprising
providing (21) a controlled current to an output of the LED driver for providing controlled illumination from a LED light source,
employing (22) a pulse width modulator having a PWM frequency to produce the controlled current,
characterized in that it comprises
setting (23) a minimum effective value of the controlled current corresponding to a maximal dimming level of a dimming range,
setting (24) the PWM frequency of the pulse width modulator to be used throughout said dimming range on the basis of the set minimum effective value of the controlled current.

8. Method according to claim 7, wherein the method comprises
producing a current having a constant nominal magnitude with an output converter (13) of the LED driver, and
pulse width modulating the current of the output converter (13) for producing the controlled current.

9. A method according to claim 7 or 8, wherein setting (23) the minimum effective value of the controlled current comprises receiving maximal dimming information.

10. A method according to claim 9, wherein
setting (23) the PWM frequency comprises selecting, on the basis of the maximal dimming information, the PWM frequency from at least two pre-selected values of selectable PWM frequencies.

Patentansprüche

1. LED-Treiber (10), umfassend

eine Ausgabe, die dafür angepasst ist, einen gesteuerten Strom zum Bereitstellen von gesteuerter Beleuchtung von einer LED-Lichtquelle (11) bereitzustellen,
einen Pulsweitenmodulator, der eine Pulsweitenmodulationsfrequenz, im Folgenden PWM-Frequenz, hat, und dafür angepasst ist, den gesteuerten Strom zu produzieren,
dadurch gekennzeichnet, dass er umfasst:

Mittel (14, 15), die dafür angepasst sind, einen Minimalwirkwert des gesteuerten Stroms festzulegen, der mit einem Maximaldimmniveau eines Dimmbereichs korrespondiert,
Mittel (14, 15), die dafür angepasst sind, die über den Dimmbereich zu verwendende PWM-Frequenz auf der Basis des festgelegten Minimalwirkwerts des gesteuerten Stroms festzulegen.

2. LED-Treiber (10) nach Anspruch 1, wobei der LED-Treiber (10) einen Ausgabewandler (13) umfasst, der dafür angepasst ist, Strom zu produzieren, der einen konstanten Nennbetrag hat, wobei der Pulsweitenmodulator dafür angepasst ist, den Strom des Ausgabewandlers (13) zum Produzieren des gesteuerten Stroms in der Pulsweite zu modulieren.

3. LED-Treiber (10) nach Anspruch 2, wobei der Ausgabewandler (13) ein Abwärtswandler ist, der eine höhere Schaltfrequenz als die PWM-Frequenz des Pulsweitenmodulators hat.

4. LED-Treiber (10) nach Anspruch 3, wobei die Ausgabe des Pulsweitenmodulators den Abwärtswandler (13) steuert, sodass während An-Perioden des in der Pulsweite modulierten Signals die Ausgabe

des Abwärtswandlers (13) eingeschaltet ist.

5. LED-Treiber (10) nach einem der Ansprüche 1 bis 4, wobei die Mittel (14. 15), die dafür angepasst sind, den Minimalwirkwert des gesteuerten Stroms festzulegen, Eingabemittel (14) zum Empfangen von Maximaldimminformation umfassen.

6. LED-Treiber (10) nach einem der Ansprüche 1 bis 5, wobei die Mittel (14, 15), die dafür angepasst sind, die PWM-Frequenz des Pulsweitenmodulators festzulegen, mindestens zwei vorausgewählte Werte von PWM-Frequenzen umfassen, die auf der Basis der Maximaldimminformation auswählbar sind.

7. Verfahren in Verbindung mit einem LED-Treiber, umfassend

Bereitstellen (21) eines gesteuerten Stroms an eine Ausgabe des LED-Treibers zum Bereitstellen gesteuerter Beleuchtung von einer LED-Lichtquelle,
Einsetzen (22) eines Pulsweitenmodulators, der eine PWM-Frequenz hat, um den gesteuerten Strom zu produzieren,
dadurch gekennzeichnet, dass es umfasst
Festlegen (23) eines Minimalwirkwerts des gesteuerten Stroms, der mit einem Maximaldimmniveau eines Dimmbereichs korrespondiert,
Festlegen (24) der über den Dimmbereich zu verwendenden PWM-Frequenz des Pulsweitenmodulators auf der Basis des festgelegten Minimalwirkwerts des gesteuerten Stroms.

8. Verfahren nach Anspruch 7, wobei das Verfahren umfasst

Produzieren eines Stroms, der einen konstanten Nennbetrag hat, mit einem Ausgabewandler (13) des LED-Treibers, und
Modulieren der Pulsweite des Stroms des Ausgabewandlers (13) zum Produzieren des gesteuerten Stroms.

9. Verfahren nach Anspruch 7 oder 8, wobei Festlegen (23) des Minimalwirkwertes des gesteuerten Stroms Empfangen von Maximaldimminformation umfasst.

10. Verfahren nach Anspruch 9, wobei
Festlegen (23) der PWM-Frequenz Auswählen der PWM-Frequenz aus mindestens zwei vorausgewählten Werten auswählbarer PWM-Frequenzen auf der Basis der Maximaldimminformation umfasst.

Revendications

1. Pilote de LED (10) comprenant
une sortie adaptée pour fournir un courant commandé pour fournir un éclairage commandé à partir d'une source de lumière LED (11),
un modulateur de largeur d'impulsions présentant une fréquence de modulation de largeur d'impulsions, ci-après fréquence PWM, et adapté pour produire le courant commandé,
caractérisé en ce qu'il comprend :

des moyens (14, 15) adaptés pour régler une valeur effective minimale du courant commandé correspondant à un niveau de gradation maximal d'une plage de gradation,
des moyens (14, 15) adaptés pour régler la fréquence PWM à utiliser dans toute ladite plage de gradation sur la base de la valeur effective minimale réglée du courant commandé.

2. Pilote de LED (10) selon la revendication 1, dans lequel le pilote de LED (10) comprend un convertisseur de sortie (13) adapté pour produire du courant présentant une grandeur nominale constante, dans lequel le modulateur de largeur d'impulsions est adapté pour moduler par largeur d'impulsions le courant du convertisseur de sortie (13) pour produire le courant commandé.

3. Pilote de LED (10) selon la revendication 2, dans lequel le convertisseur de sortie (13) est un convertisseur dévolteur présentant une fréquence de commutation plus grande que la fréquence PWM du modulateur de largeur d'impulsions.

4. Pilote de LED (10) selon la revendication 3, dans lequel la sortie du modulateur de largeur d'impulsions commande le convertisseur dévolteur (13) de sorte que pendant des périodes actives du signal modulé par largeur d'impulsions la sortie du convertisseur dévolteur (13) est activée.

5. Pilote de LED (10) selon l'une quelconque des revendications précédentes 1 à 4, dans lequel les moyens (14, 15) adaptés pour régler la valeur effective minimale du courant commandé comprennent des moyens d'entrée (14) pour recevoir des informations de gradation maximale.

6. Pilote de LED (10) selon l'une quelconque des revendications précédentes 1 à 5, dans lequel les moyens (14, 15) adaptés pour régler la fréquence PWM du modulateur de largeur d'impulsions comprennent au moins deux valeurs présélectionnées de fréquences PWM qui sont sélectionnables sur la base des informations de gradation maximale.

7. Procédé en lien avec un pilote de LED comprenant fournir (21) un courant commandé à une sortie du pilote de LED pour fournir un éclairage commandé

à partir d'une source de lumière LED,
employer (22) un modulateur de largeur d'impulsions présentant une fréquence PWM pour produire le courant commandé,
caractérisé en ce qu'il comprend
régler (23) une valeur effective minimale du courant commandé correspondant à un niveau de gradation maximal d'une plage de gradation,
régler (24) la fréquence PWM du modulateur de largeur d'impulsions à utiliser dans toute ladite plage de gradation sur la base de la valeur effective minimale réglée du courant commandé.

8. Procédé selon la revendication 7, dans lequel le procédé comprend
produire un courant présentant une grandeur nominale constante avec un convertisseur de sortie (13) du pilote de LED, et
moduler par largeur d'impulsions le courant du convertisseur de sortie (13) pour produire le courant commandé.

9. Procédé selon la revendication 7 ou 8, dans lequel régler (23) la valeur effective minimale du courant commandé comprend recevoir des informations de gradation maximale.

10. Procédé selon la revendication 9, dans lequel
régler (23) la fréquence PWM comprend sélectionner, sur la base des informations de gradation maximale, la fréquence PWM à partir d'au moins deux valeurs présélectionnées de fréquences PWM sélectionnables.

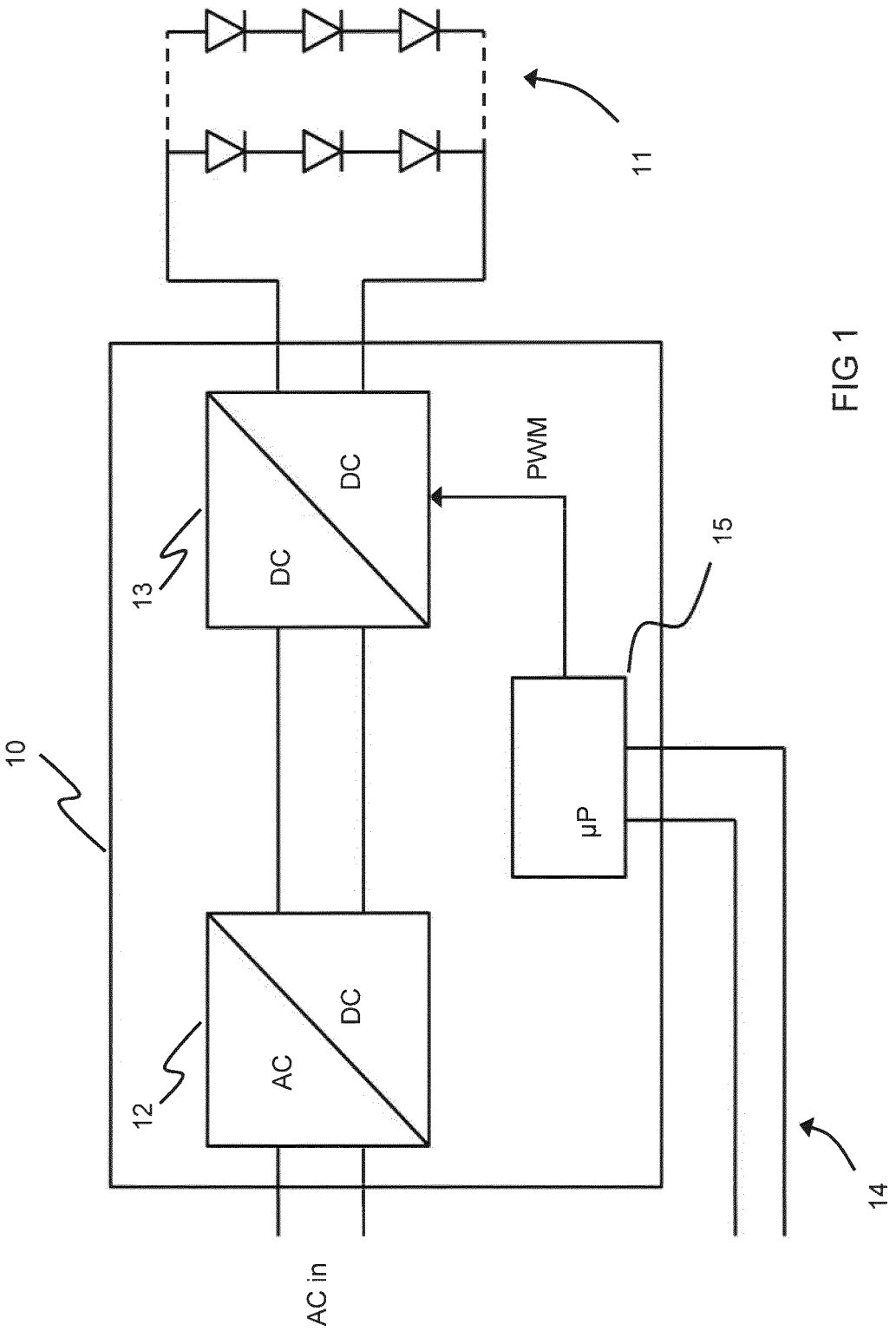


FIG 1

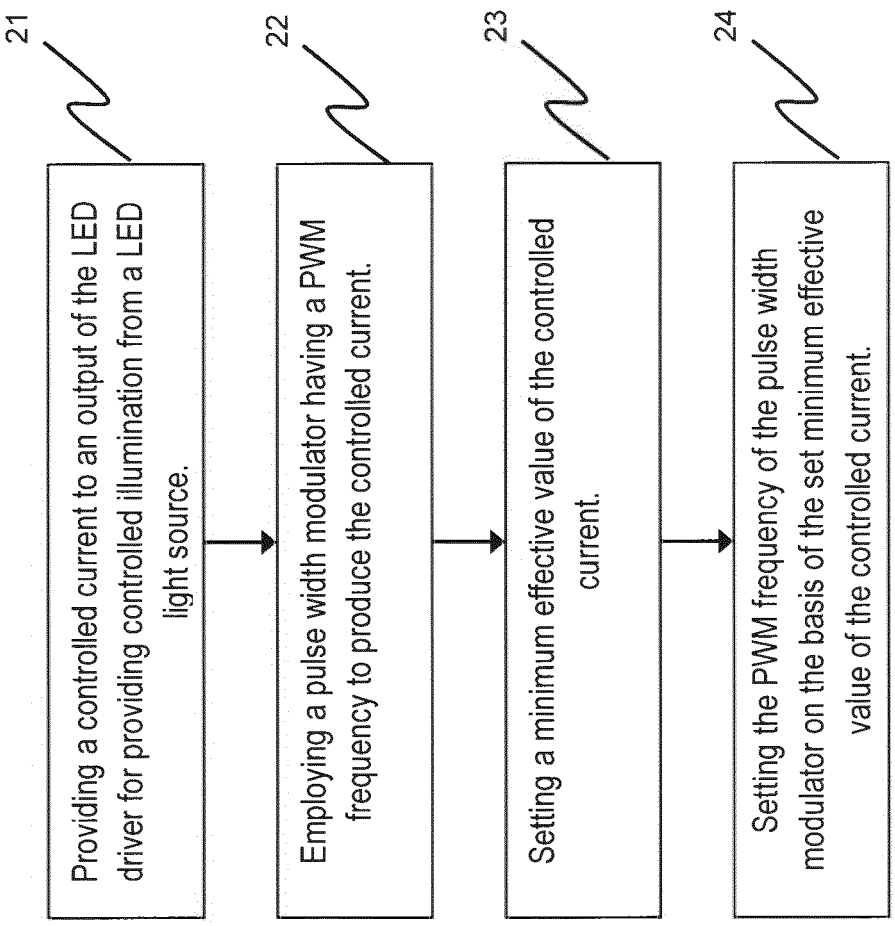

21
Providing a controlled current to an output of the LED driver for providing controlled illumination from a LED light source.
22
Employing a pulse width modulator having a PWM frequency to produce the controlled current.
23
Setting a minimum effective value of the controlled current.
24
Setting the PWM frequency of the pulse width modulator on the basis of the set minimum effective value of the controlled current.

FIG 2

REFERENCES CITED IN THE DESCRIPTION

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