(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
17 July 2014 (17.07.2014)

WIPO | PCT

(10) International Publication Number
WO 2014/108249 A1

(51) International Patent Classification:
H05B 33/08 (2006.01) *H05B 37/02* (2006.01)

(21) International Application Number:
PCT/EP2013/075126

(22) International Filing Date:
29 November 2013 (29.11.2013)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
13151016.6 11 January 2013 (11.01.2013) EP

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(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

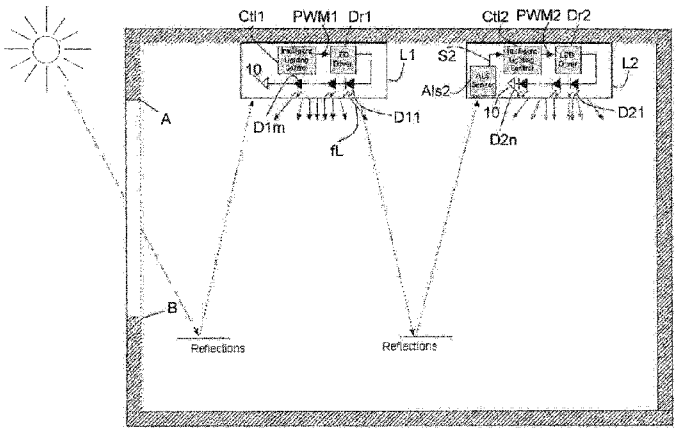
(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

— *with international search report (Art. 21(3))*

(54) Title: ELECTRONIC LIGHTING SYSTEM AND METHOD FOR LIGHTING SYNCHRONIZATION AND SYNCHRONIZATION OF PWM DRIVE SIGNALS FOR THE REMOVAL OF OPTICAL SUB-HARMONICS

Fig1



(57) Abstract: In one embodiment, an electronic lighting system comprises a first light source (L1) adapted to emit light with a first brightness as a function of a first driving signal (PWM1) having a first frequency (f1), at least one second light source (L2) having a main light sensor (Als2) for providing an brightness of light surrounding the second light source (L2), wherein the first light source (L1) is arranged in visual connection with the at least one second light source (L2). Thereby, the second light source (L2) is prepared to emit light with a second brightness as a function of a second driving signal (PWM2) with a second frequency (f2), the second frequency (f2) of the second driving signal (PWM2) being adjusted to a light frequency (fL) of the light emitted by the first light source (L1), the light frequency (fL) being detected by means of the main light sensor (Als2). Furthermore, a method for lighting synchronization is described.

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Description

ELECTRONIC LIGHTING SYSTEM AND METHOD FOR LIGHTING SYNCHRONIZATION AND SYNCHRONIZATION OF PWM DRIVE SIGNALS FOR THE REMOVAL OF OPTICAL SUB-HARMONICS

The application refers to an electronic lighting system and to a method for lighting synchronization.

Light-emitting diodes, LEDs, are used more and more in the field of architectural lighting. One of their main advantages is that LEDs can be dimmed precisely and efficiently according to various needs. By this, light colour and light brightness, for instance, can be adjusted, also taking into account ambient light conditions.

The present application refers to light sources based on LEDs which are operated by constant current sources driven with a pulse-width-modulated signal.

As soon as more than one light source are mounted in a single room, each light source is driven with a slightly different frequency and/or phase. The use of various frequencies in various lights leads to a slow overall variation of the phase relationship between the frequencies, which causes sub-harmonics or beat frequencies. These beat frequencies have an adverse effect on human beings.

It is therefore an objective to provide an electronic lighting system and a corresponding method which overcome the described deficiencies.

The objective is achieved by the subject matter of the independent patent claims. Embodiments and developments of the invention are subject matter of the dependent claims.

In one embodiment, an electronic lighting system comprises a first light source and at least one second light source. The first light source and the at least one second light source are arranged in visual connection with each other. The first light source is adapted to emit light with a first brightness as a function of a first driving signal having a first frequency. The at least one second light source has a main light sensor for providing a brightness of light surrounding the second light source. Thereby, the second light source is prepared to emit light with a second brightness as a function of a second driving signal with a second frequency. The second frequency of the second driving signal is adjusted to a light frequency of the light emitted by the first light source. The light frequency is detected by means of the main light sensor.

The first light source is switched on and emits light with a first brightness according to the first driving signal with the first frequency. The main light sensor within the second light source checks within a specified frequency range for other lights working in the same room. The main light sensor detects the light emitted by the first light source, especially the light frequency of the emitted light. The second frequency of the second driving signal is adjusted to the detected light frequency within the second light source. Subsequently, the second light source is activated and emits light with the second brightness according to the second driving signal using the second frequency.

The second frequency used to drive the second light source is adjusted to the detected light frequency of light emitted by the first light source. The light frequency of the light emitted by the first light source corresponds to the first frequency used in driving the first light source. Consequently, the second frequency used within the at least one second light source is synchronized with the first frequency used within the first light source. This results in a synchronization of first and second driving signals at least with respect to the value of the respective frequency. A constant phase difference between first and second driving signals at this synchronized frequency wherein the second driving signal is delayed with respect to the first driving signal may also arise. Preferably, first and second driving signals are in synchronization regarding the value of the respective frequency and phase.

Advantageously, when overlaying these two frequencies, no sub-harmonics or beat frequencies arise. Human beings feel much more comfortable in rooms where the invention has been installed.

First and second light sources are arranged in visual connection with each other, i.e. in line of sight with each other. They can also be installed in one single room.

The first and second light sources each employ one or more LEDs. These LEDs are driven by first and second driving signals, respectively, for which a pulse-width-modulated signal is used in each case. The brightness of the light emitted by each of the LEDs is a function of a ratio of on-time to off-time of the respective pulse-width-modulated driving signal.

Thereby, the first light source can be configured as a master device, whereas the at least one second light source and each further light source using the same implementation as the at least one second light source can be configured as slave devices.

The characteristic frequency range in which the at least one second light source checks, by means of its main light sensor, for other light sources present is in the range of its own frequency. The own frequency is a pre-defined frequency which is generally used for driving the kind of LEDs employed in the light source. For example, the at least one second light source checks in the range of 10 Hz to 1 KHz.

Brightness is a term that describes how intense a light source is perceived by the human eye. Brightness is measured in the units called “LUX”.

In one development, the light frequency of the light emitted by the first light source is a function of the first frequency of the first driving signal.

In a further development, the first light source comprises a first control unit and a first driver circuit connected to an output of the first control unit. The first control unit is prepared to generate the first driving signal with a first duty cycle as a function of the first brightness. The first driver circuit is prepared to be connected to at least one light-emitting diode and is further prepared to drive the at least one light-emitting diode as a function of the first driving signal.

The first control unit generates the first driving signal, which is used within the first driver circuit to drive connected LEDs.

The duty cycle is thereby defined as the ratio between the on-time or the active period of the first driving signal and its total period.

In a further embodiment, the first light source comprises an additional light sensor which is adapted to measure a brightness of light surrounding the first light source and to provide a first sensor signal as a function of the measured brightness. The first driving signal is adapted as a function of the first sensor signal.

By means of the additional light sensor in the first light source, light emitted by the first light source can be adapted to ambient light conditions.

In an exemplary implementation, the additional light sensor of the first light source is used to measure brightness during the off-time of the period of the first driving signal, which is pulse-width-modulated.

In another embodiment, the first light source comprises a first communication module for providing an adjusted first driving signal such that at least one additional light pulse representing at least one control parameter is emitted by the first light source during an off-period of the first driving signal.

Said off-period of the first driving signal is advantageously used for sending the at least one control parameter to the at

least one second light source. As the off-periods of the first and second driving signals are taking place at the same point in time as the first and second driving signals are synchronized with each other, the control parameter sent by the first light source can be detected by the first light source also during the off-time of its second driving signal.

One example of a control parameter is the colour temperature. For sending the at least one control parameter from the first light source to other light sources present in the same room, especially the at least one second light source, visual communication, for instance according to the standard IEEE 802.15.7, is employed as to the knowledge of a person skilled in the art.

In a further development, the first communication module comprises a coding unit, and a modulation unit which is coupled to an output of the coding unit. The coding unit provides a coded signal as a function of the first driving signal and the control parameter supplied by a data signal. The modulation unit is prepared to provide the adjusted first driving signal as a function of the coded signal.

The control parameter supplied via the data signal is encoded in the coding unit using the first driving signal. The obtained coded signal is modulated into the adjusted first driving signal. The adjusted first driving signal is provided to the first driver circuit resulting in short activation of the connected LEDs during the off-time of the first driving signal. The coding unit uses, for instance, Manchester coding to guarantee clock transmission. The modulation unit employs, for example, amplitude modulation to transfer the desired information, here the control parameter.

The main light sensor used in the second light source and the additional light sensor used in the first light source can be implemented for example using a photodiode. This photodiode can be connected to an amplifier and respective signal processing. Each light sensor consequently provides at least the frequency of the light surrounding the sensor and the brightness reflected in the amount of current output by the sensor. A light sensor is also denoted an ambient light sensor.

In an exemplary implementation, the control parameter is supplied by the first control unit. In another example, the additional light sensor of the first light source measures the ambient light, from which the first control circuit determines a colour temperature according to the time of day and transmits the colour temperature to other light sources arranged in the same room.

In another embodiment, the second light source comprises a second control unit and a second driver circuit connected to an output of the second control unit. The second control unit is coupled to an output of the main light sensor and is prepared to generate the second driving signal. The second driver circuit is prepared to be connected to at least one light-emitting diode and to drive the at least one light-emitting diode as a function of the second driving signal. The main light sensor is adapted to provide a second sensor signal as a function of the detected light frequency and a detected brightness of the light emitted by the first light source.

The main light sensor provides the second sensor signal as a function of the detected light frequency of the light emitted

by the first light source and as a function of the detected brightness of the light emitted by the first light source. The second control unit generates the second driving signal as a function of information provided via the second sensor signal. The second driver circuit uses the second driving signal to operate connected LEDs.

By means of the main light sensor, the second driving signal can be adapted in its frequency to the first frequency of the first driving signal. Furthermore, other parameters, like the colour temperature, can be adapted to the parameter used within the first light source which is received by the main light sensor.

In a development, the second light source further comprises a second communication module which is connected between the main light sensor and the second control unit. The second communication module is further prepared to provide a modified second sensor signal comprising the at least one control parameter emitted by the first light source.

In a development, the second communication module comprises a demodulation unit, a clocking unit coupled to an output of the demodulation unit, and a decoding unit coupled to an output of the clocking unit. The demodulation unit provides a demodulated signal as a function of the second sensor signal. The clocking unit provides a received data signal as a function of the demodulated signal and a clocking signal. The decoding unit provides the modified second sensor signal as a function of the received data signal and the clocking signal.

The second communication module together with its units implements all the functionality necessary for communication

with the first communication module within the first light source, especially for receiving the at least one control parameter. A light signal comprising the control parameter is detected in the main light sensor and is propagated by means of the second sensor signal. The demodulation unit demodulates the second sensor signal and provides the demodulated signal. The clocking unit therefrom recovers the clock into the clocking signal and provides the received data signal. The decoding unit decodes the at least one control parameter from the received data signal using the clocking signal and provides the modified second sensor signal.

Using the at least one control parameter conveyed within the modified second sensor signal, the second control unit is enabled to adapt the second frequency of the second driving signal or an amount of current provided within the second driver circuit.

The transmission and reception of the at least one control parameter are effected during the synchronized off-periods of first and second driving signals.

The first and second driver circuits are each implemented by at least one controlled current source, for example. The controlled current source is controlled by the respective driving signal.

In one embodiment, a method for lighting synchronization comprises the following steps:

- generating a first driving signal having a first frequency within a first light source,

- activating the first light source to emit light with a first brightness as a function of the first driving signal,
- measuring a light frequency of the light emitted by the first light source within a second light source which is in visual connection with the first light source,
- generating a second driving signal having a second frequency within the second light source,
- adjusting the second frequency to the measured light frequency, and
- activating the second light source to emit light with a second brightness as a function of the second driving signal.

Advantageously, LED based light sources within one room are synchronized in terms of pulse width modulation frequencies used within these light sources by means of the described method. Well being of persons in this room is enhanced.

In a development the method further comprises:

- transmitting at least one control parameter by the first light source using visual light communication,
- receiving the at least one control parameter by the second light source using a main light sensor,
- wherein the acts of transmitting and receiving are effected during an off-period of the first driving signal.

As the off-period of the first driving signal is synchronous to, e.g. taking place concurrently with, the off-period of the second driving signal, during this off period the ambient light can be measured. Subsequently, brightness of the light

sources can be set according to actual demand. Advantageously, thereby the sum of ambient light and artificial light, e.g. the light emitted by the light sources, can be kept constant and an optimum of energy saving is achieved. In addition, driving signals of first and second light sources can be re-synchronized from time to time.

The text below explains the invention in detail using exemplary embodiments with reference to the drawings. Components and circuit elements that are functionally identical or have the identical effect bear identical reference numbers. In so far as circuit parts or components correspond to one another in function, a description of them will not be repeated in each of the following figures. Therein:

Figure 1 shows an exemplary embodiment of an electronic lighting arrangement according to the proposed principle,

Figure 2 shows signal diagrams referring to the state of the art LED lighting,

Figure 3 shows signal diagrams referring to the embodiment of Figure 1, and

Figure 4 shows a second exemplary embodiment of an electronic lighting arrangement according to the proposed principle.

Figure 1 shows an exemplary embodiment of the electronic lighting arrangement according to the proposed principle. A first light source L1 and a second light source L2 are

arranged in one room. This room has a window extending between points A and B. The first light source L1 comprises a first control unit Ctl1 and a first driver circuit Dr1. The first light source L1 further has a number m of LEDs D11, D12, …, D1m connected in series to the first driver circuit DR1.

The first control unit Ctl1 provides a first driving signal PWM1 to the first driver circuit Dr1. The first driver signal PWM1 is a pulse width modulated signal having a first frequency f1. The first driver circuit Dr1 drives the connected LEDs D11, …, D1m using the first driving signal PWM1. Thereby, LEDs D11, …, D1m are connected in series to each other, the first LED D11 being connected to an output of the first driver circuit Dr1. The LEDs D11, …, D1m are referred to a reference potential terminal 10.

The second light source L2 comprises a main light sensor Als2, a second control unit Ctl2 and a second driver circuit Dr2. The second light source L2 has a number n of LEDs D21, D22, …, D2n which are connected in series to each other at an output of the second driver circuit Dr2. The LEDs D21, …, D2n are likewise referred to the reference potential terminal 10.

The main light sensor Als2 provides a second sensor signal S2 as a function of a brightness of light surrounding the second light source L2 to the second control unit Ctl2. The second control unit Ctl2 provides a second driving signal PWM2 as a function of the second sensor signal S2. The second driver circuit Dr2 controls the connected diodes D21, …, D2n using the second driving signal PWM2.

The first light source L1 is switched on first. It emits light with a first brightness as a function of the first driving signal PWM1. The light emitted by the first light source L1 accordingly has a light frequency fL. The second light source L2 senses for ambient light within characteristic frequencies in the range of its own second driving signal PWM2 by means of the main light sensor Als2. It detects the light frequency fL of the light emitted by the first light source L1. The second light source L2 subsequently adapts a second frequency f2 of the second driving signal PWM2 to the detected light frequency fL. A frequency reference used within the second light source L2 to generate the second frequency f2 of the second driving signal PWM2 is adjusted to be synchronous with the sensed light frequency fL. As soon as this synchronization is achieved, the second light source L2 turns on its LEDs D21, …, D2n.

As the light frequency fL emitted by LEDs D11, …, D1m of the first light source L1 is a function of the first frequency f1 of the first driving signal PWM1, the second frequency f2 used within the second driving signal PWM2 is synchronized to the first frequency f1. Thereby, advantageously adverse effects resulting from beat frequencies of sub-harmonics of LED lights driven with slightly different frequencies, seen as flickering by human beings in the room, are avoided.

Figure 2 shows signal diagrams referring to state of the art LED lighting. Every signal is depicted as progression over time of amplitude for a pulse width modulated signal. The top diagram shows the progression of signal a which is used for driving a first LED light. The diagram in the middle presents the progression of signal b which is used for driving a second LED light. The frequency of signal b is 4% higher than

the frequency of signal a. The diagram in the bottom shows a progression of the resulting sum signal c of signal a and signal b. This resulting signal c is experienced by a person in the room together with the first and the second LED lights.

As can be seen, the slight difference of frequencies between signal a and signal b generates a slow variation of the duty cycle of the resulting sum signal c. Arrows 1 indicate points where the duty cycle of the sum signal c is 50% and the amplitude is double the amplitude of signal a and b. Arrows 2 indicate points where the duty cycle of the sum signal c is 100%, whereas the amplitude is only at 1. This results in a beat frequency which is defined by the difference of the frequencies used in signals a and b according to the following equation:

$$fbeat = fb - fa$$

Therein, fbeat represents the beat frequency, fa represents the frequency of the signal a and fb represents the frequency of the signal b.

This beat frequency fbeat results in flicker which has adverse effects on human wellbeing.

This signal diagrams show state of the art implementations and are only used for reasons of comparison to demonstrate the effect of the described invention.

Figure 3 shows signal diagrams referring to the embodiment depicted in Figure 1. The top diagram shows progression over time of the first driving signal PWM1 used in the first light

source L1. The diagram in the middle shows the progression of the second driving signal PWM2 used within the second light source L2. The diagram in the bottom shows the resulting sum signal of first driving signal PWM1 and second driving signal PWM2 as experienced by a person in the same room with first and second light sources L1, L2.

As the frequencies of the first and the second driving signal PWM1, PWM2 are synchronized with each other as described above, no beat frequencies occur in the summation of the first and the second driving signals PWM1, PWM2. This enhances the wellbeing of persons confronted with first and second light sources L1, L2.

Synchronized off periods of the first and the second driving signal PWM1, PWM2 can be discerned at time intervals in which the sum signal in the bottom diagram has an amplitude value of zero.

Figure 4 shows a second exemplary embodiment of the electronic lighting arrangement according to the proposed principle. This embodiment is based on the same components as the embodiment of Figure 1. Extra components are added to achieve additional functionality. As in Figure 1, first and second light sources L1, L2 are mounted in the same room in visual connection with each other.

The first light source L1 has an additional light sensor Als1 connected to an input of the first control unit Ctl1. The additional light sensor Als1 provides a first sensor signal S1 as a function of a measured brightness of light surrounding the first light source L1. The first light source L1 also comprises a first communication module Com1. The

first communication module Com1 is connected to outputs of the first control unit Ctl1. The first control unit Ctl1 is further adapted to provide a first clock signal CLK1 and a data signal DS which comprises at least one control parameter to the first communication module Com1. The first communication module Com1 is adapted to provide an adjusted first driving signal PWM1a such that at least one additional light pulse representing the at least one control parameter is emitted by the first light source L1 during an off period of the first driving signal PWM1.

The first communication module Com1 comprises a coding unit Cod, and a modulation unit Mod coupled to an output of the coding unit Cod. The coding unit Cod provides a coded signal CS as a function of the first clock signal CLK1 and the control parameter supplied by the data signal DS. The modulation unit Mod provides the adjusted first driving signal PWM1a as a function of the coded signal CS.

The second light source L2 comprises, in addition to the embodiment of Figure 1, a second communication module Com2 which is connected between the main light sensor Als2 and the second control unit Ctl2. The second communication module Com2 receives the second sensor signal S2 and therefrom provides a modified second sensor signal S2a comprising the at least one control parameter emitted by the first light source L1 and sensed by means of the main light sensor Als2.

In detail, the second communication module Com2 comprises a demodulation unit Demod, a clocking unit Cl and a decoding unit Decod. The demodulation unit Demod provides a demodulated signal DMS as a function of the second sensor signal S2. The clocking unit Cl is coupled to an output of

the demodulation unit Demod. The clocking unit Cl is prepared to provide a received data signal RDS as a function of the demodulated signal DMS and a second clock signal CLK2. The decoding unit Decod is coupled to outputs of the clocking unit Cl. The decoding unit Decod is prepared to provide the modified second sensor signal S2a as a function of the received data signal RDS and the second clock signal CLK2.

The additional light sensor Als1 in the first light source L1 senses light surrounding the first light source L1 and provides respective measured values within the first sensor signal S1. During off periods of the first driving signal PWM1 ambient light can be sensed. During on periods of the first driving signal PWM1, i.e. when the LEDs D11, ..., D1n are switched on, colour temperature is measured. The first control unit Ctl1 determines from the first sensor signal S1 a control parameter which is to be transmitted to other light sources in the same room, here the second light source L2. The control parameter indicative of e.g. a light temperature or a synchronisation parameter is provided to the first communication module Com1 by means of the data signal DS together with a respective clock represented by the first clock signal CLK1. The control parameter is encoded, e.g. using Manchester coding, in the coding unit Cod and modulated, e.g. amplitude modulated, in the modulation unit Mod. During an off-period of the first driving signal PWM1, the control parameter is sent to the second light source by shortly switching on LEDs within the first light source L1 according to the modified first driving signal PWM1a.

During the corresponding synchronized off period of the second driving signal PWM2, the main light sensor Als2 within the second light source L2 senses for ambient light and

detects the additional pulses sent out by the first light source L1. These pulses are demodulated in the demodulation unit Demod, decoded according to a second clock signal CLK2 recovered in the clocking unit Cl and provided as modified second sensor signal S2a to the second control unit Ctl2. The second control unit Ctl2 can adapt its second driving signal PWM2 according to the received control parameter.

By this, advantageously a resynchronization of first and second light sources L1, L2 can be achieved during off periods of the synchronized driving signals PWM1, PWM2. In addition, other parameters, e.g. color temperature, can be adjusted to values measured and provided by the first light source L1.

Furthermore, changes in ambient light due to time of day can be sensed by the first light source L1. Brightness of the LEDs within L1 and L2 can be adapted accordingly. For instance, light coming in by a window, e.g. the window AB in Figure 1, is measured by the additional light sensor Als1 in the first light source L1. Brightness of the LEDs in the first light source L1 is adjusted by setting the duty cycle of the first driving signal PWM1. A suitable control parameter is subsequently sent to the second light source L2 which in turn can adapt its second driving signal PWM2.

In an alternative embodiment, power line communication is used to transmit control parameters from first to second light source L1, L2.

Reference list

L1, L2	light source
PWM1, PWM2, PWM1a	driving signal
S1, S2, S2a	sensor signal
Ctl1, Ctl2	control unit
Dr1, Dr2	driver circuit
Als1, Als2	light sensor
f1, f2, fL	frequency
D11, …, D1m	light-emitting diode
D21, …, D1n	light-emitting diode
Com1, Com2	communication module
Cod	coding unit
Mod	modulation unit
DS	data signal
CS	coded signal
DMS	demodulated signal
RDS	received data signal
CLK1, CLK2	clock signal
Demod	demodulation unit
Cl	clocking unit
Decod	decoding unit
10	reference potential terminal
A, B	point
1, 2	arrow

Claims

1. Electronic lighting system comprising
- a first light source (L1) adapted to emit light with a first brightness as a function of a first driving signal (PWM1) having a first frequency (f1),
- at least one second light source (L2) having a main light sensor (Als2) for providing an brightness of light surrounding the second light source (L2),
wherein the first light source (L1) is arranged in visual connection with the at least one second light source (L2), and
wherein the second light source (L2) is prepared to emit light with a second brightness as a function of a second driving signal (PWM2) with a second frequency (f2), the second frequency (f2) of the second driving signal (PWM2) being adjusted to a light frequency (fL) of the light emitted by the first light source (L1), the light frequency (fL) being detected by means of the main light sensor (Als2).

2. Electronic lighting system according to claim 1, wherein the light frequency (fL) of the light emitted by the first light source (L1) is a function of the first frequency (f1) of the first driving signal (PWM1).

3. Electronic lighting system according to claim 1 or 2, wherein the first light source (L1) comprises
- a first control unit (Clt1) which is prepared to generate the first driving signal (PWM1) with a first duty cycle as a function of the first brightness, and
- a first driver circuit (Dr1) connected to an output of the first control unit (Ctl1), the first driver circuit

(Dr1) being prepared to be connected to at least one light-emitting diode (D11) and to drive the at least one light-emitting diode (D11) as a function of the first driving signal (PWM1).

4. Electronic lighting system according to any of claims 1 to 3,
wherein
- the first light source (L1) comprises an additional light sensor (Als1) which is adapted to measure a brightness of light surrounding the first light source (L1) and to provide a first sensor signal (S1) as a function of the measured brightness, and
- the first driving signal (PWM1) is adapted as a function of the first sensor signal (S1).

5. Electronic lighting system according to any of claims 1 to 4,
wherein the first light source (L1) comprises a first communication module (Com1) for providing an adjusted first driving signal (PWM1a) such that at least one additional light pulse representing at least one control parameter is emitted by the first light source (L1) during an off-period of the first driving signal (PWM1).

6. Electronic lighting system according to claim 5,
wherein the first communication module (Com1) comprises
- a coding unit (Cod) which provides a coded signal (CS) as a function of a first clock signal (CLK1) and the control parameter supplied by a data signal (DS), and
- a modulation unit (Mod) which is coupled to an output of the coding unit (Cod), the modulation unit (Mod)

being prepared to provide the adjusted first driving signal (PWM1a) as a function of the coded signal (CS).

7. Electronic lighting system according to any of claims 1 to 6,
wherein the second light source (L2) comprises
- a second control unit (Clt2) which is coupled to an output of the main light sensor (Als2) and which is prepared to generate the second driving signal (PWM2), and
- a second driver circuit (Dr2) connected to an output of the second control unit (Ctl2), the second driver circuit (Dr1) being prepared to be connected to at least one light-emitting diode (D21) and to drive the at least one light-emitting diode (D21) as a function of the second driving signal (PWM2),
and wherein the main light sensor (Als2) is adapted to provide a second sensor signal (S2) as a function of the detected light frequency (fL) and a detected brightness of the light emitted by the first light source (L1).

8. Electronic lighting system according to any of claims 5 to 7,
wherein the second light source (L2) further comprises a second communication module (Com2) which is connected between the main light sensor (Als2) and the second control unit (Ctl2), the second light source (L2) being prepared to provide a modified second sensor signal (S2a) comprising the at least one control parameter emitted by the first light source (L1).

9. Electronic lighting system according to claim 8,
wherein the second communication module (Com2) comprises

- a demodulation unit (Demod) for providing a demodulated signal (DMS) as a function of the second sensor signal (S2),
- a clocking unit (Cl) coupled to an output of the demodulation unit (Demod), the clocking unit (Cl) being prepared to provide a received data signal (RDS) as a function of the demodulated signal (DMS) and a second clock signal (CLK2), and
- a decoding unit (Decode) coupled to an output of the clocking unit (Cl), the decoding unit (Decode) being prepared to provide the modified second sensor signal (S2a) as a function of the received data signal (RDS) and the second clock signal (CLK2).

10. Method for lighting synchronization comprising the following steps:
- generating a first driving signal (PWM1) having a first frequency (f1) within a first light source (L1),
- activating the first light source (L1) to emit light with a first brightness as a function of the first driving signal (PWM1),
- measuring a light frequency (fL) of the light emitted by the first light source (L1) within a second light source (L2) which is in visual connection with the first light source (L1),
- generating a second driving signal (PWM2) having a second frequency (f2) within the second light source (L2),
- adjusting the second frequency (f2) to the measured light frequency (fL), and

- activating the second light source (L2) to emit light with a second brightness as a function of the second driving signal (PWM2).

11. Method according to claim 10, further comprising:
- measuring an brightness of light surrounding the first light source (L1) within the first light source (L1) during an off-period of the first driving signal (PWM1),
- adapting the first driving signal (PWM1) as a function of the measured light brightness.

12. Method according to claim 10 or 11, further comprising:
- transmitting at least one control parameter by the first light source (L1) using visual light communication,
- receiving the at least one control parameter by the second light source (L2) using a main light sensor (Als2),
- wherein the acts of transmitting and receiving are effected during an off-period of the first driving signal (PWM1).

13. Method according to claim 12,
the act of transmitting comprising:
- encoding the at least one control parameter,
- modulating the encoded control parameter, and
- emitting light using the modulated encoded control parameter.

14. Method according to claim 13,
the act of receiving comprising:

- demodulating the at least one modulated encoded control parameter,
- decoding the encoded control parameter,
- recovering a clock signal (CLK), and
- providing a modified second sensor signal (S2a) as a function of the at least one control parameter.

Fig1

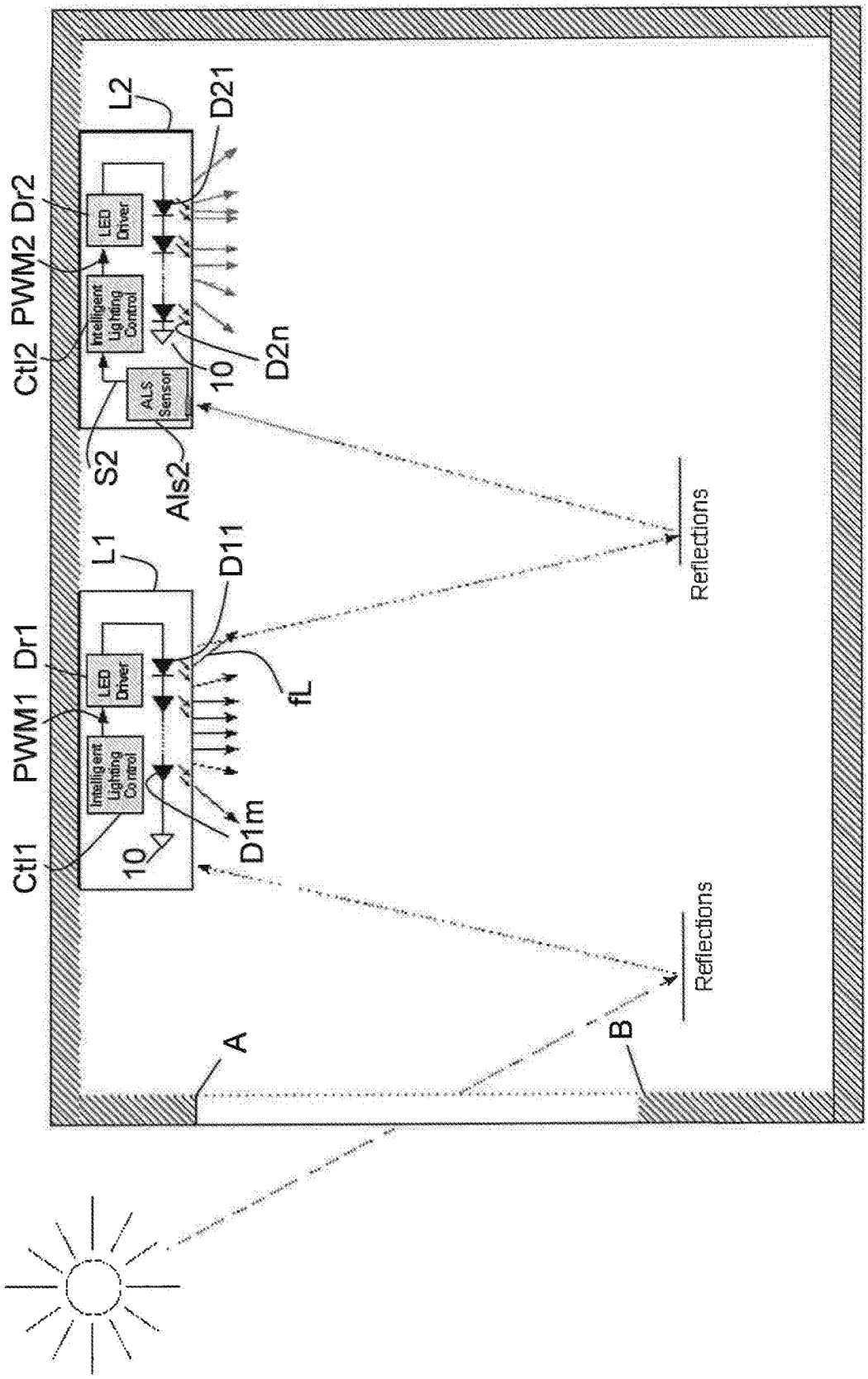

L2
D21
Dr2
PWM2
LED Driver
Intelligent Lighting Control
Ctl2
ALS Sensor
10
D2n
S2
Als2
L1
D11
Dr1
PWM1
LED Driver
Intelligent Lighting Control
Ctl1
10
D1m
fL
Reflections
Reflections
A
B

Fig 2

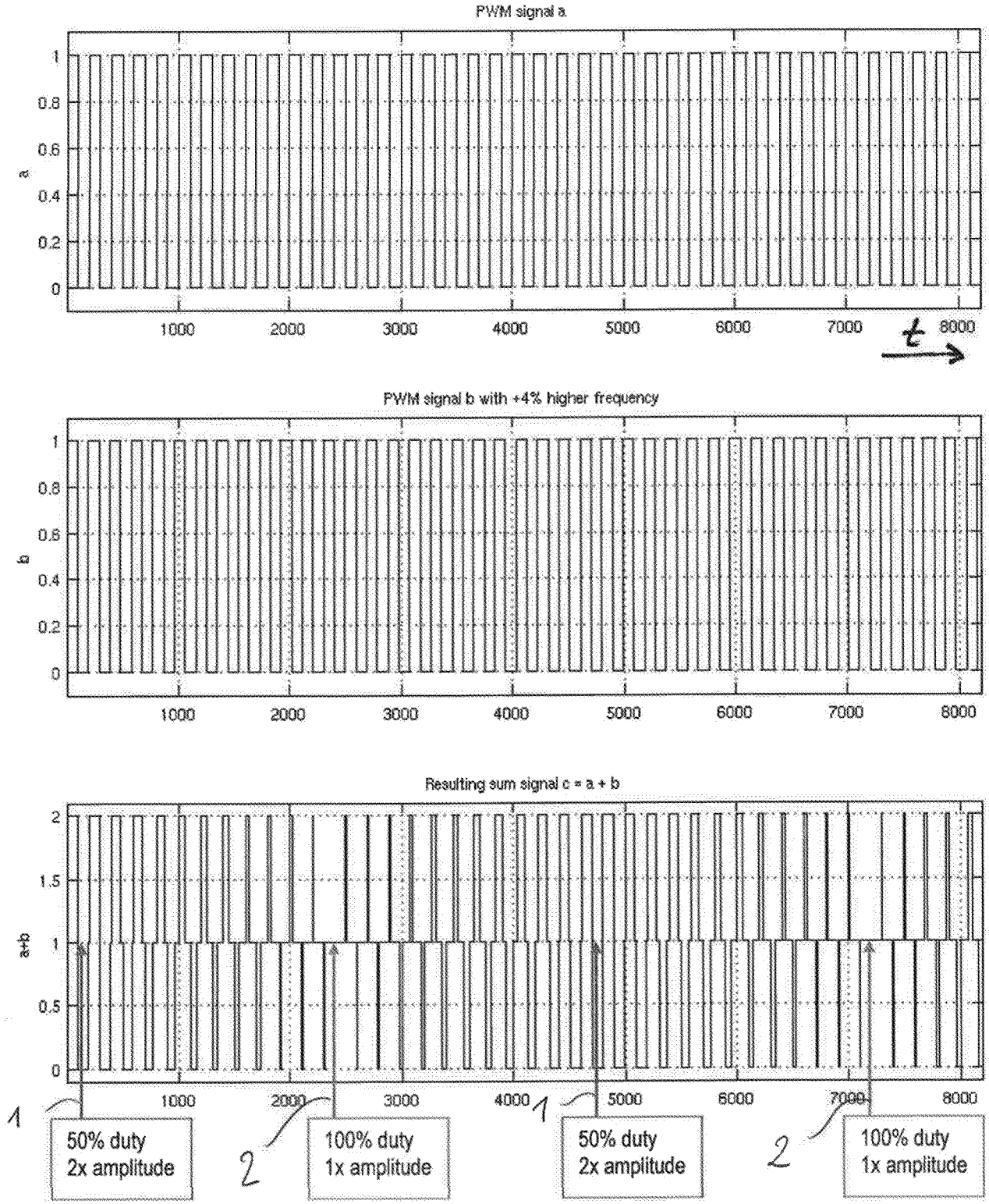

PWM signal a
a
t
PWM signal b with +4% higher frequency
b
Resulting sum signal c = a + b
a+b
1
50% duty
2x amplitude
2
100% duty
1x amplitude
1
50% duty
2x amplitude
2
100% duty
1x amplitude

Fig 3

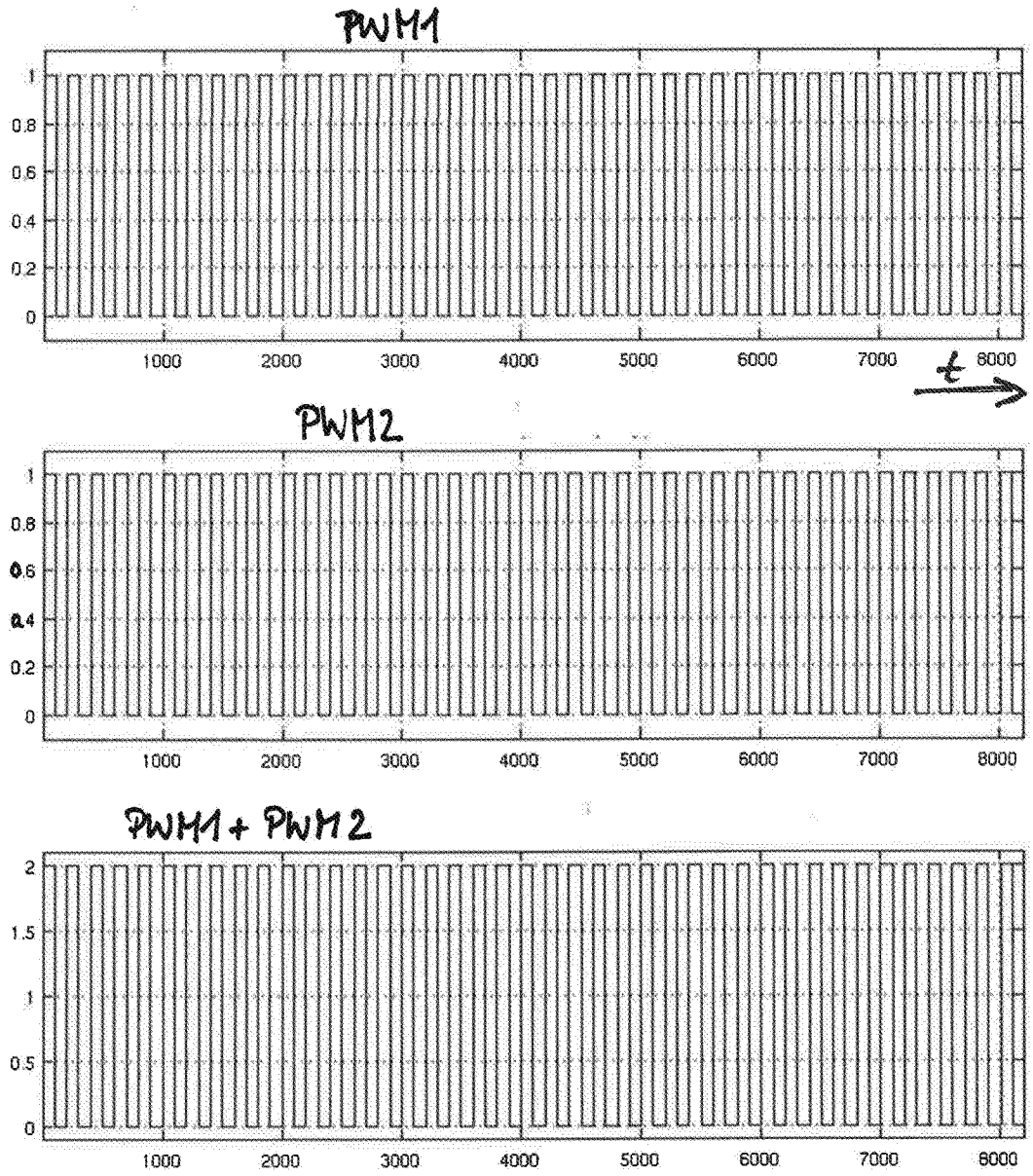
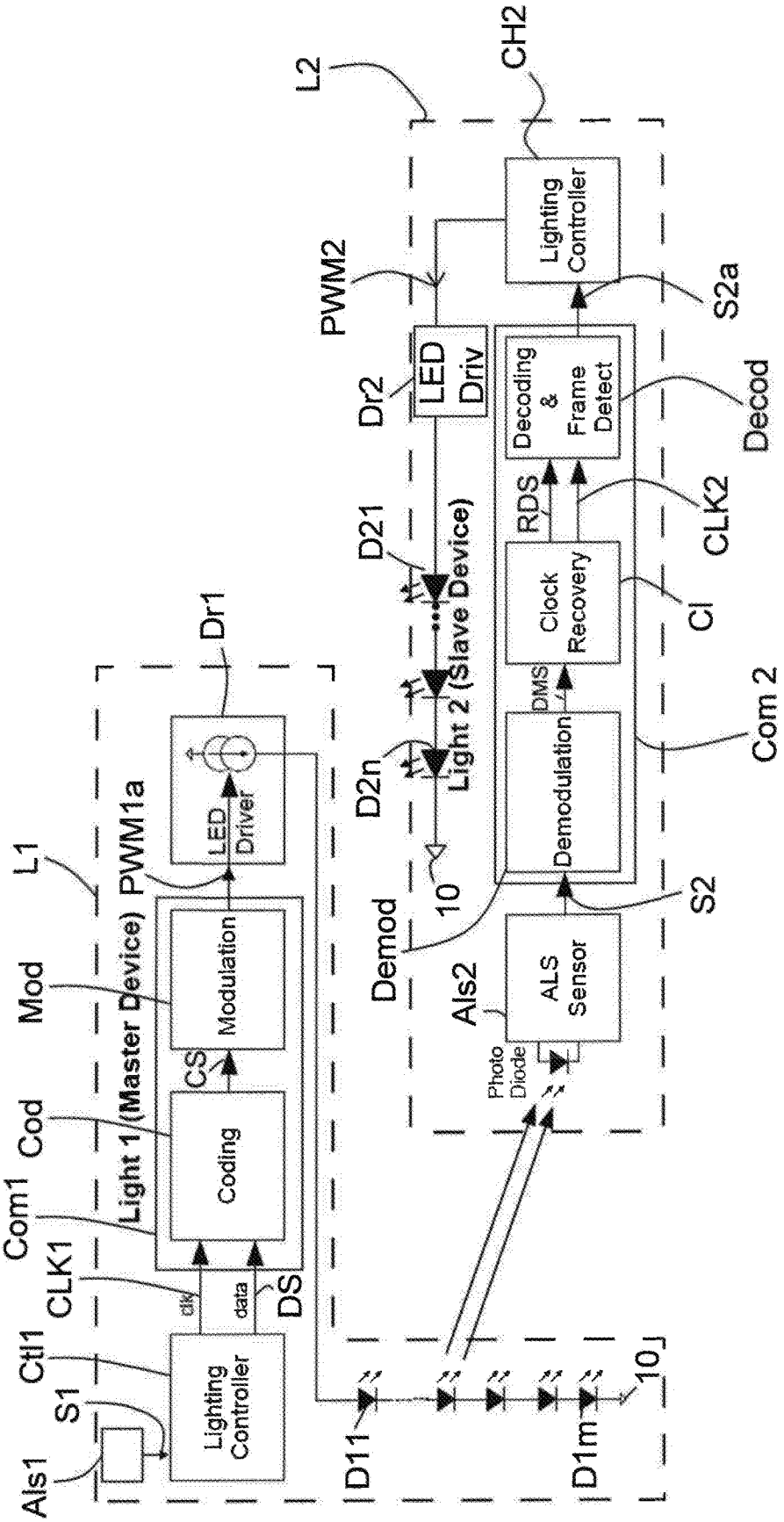

PWM1
1
0.8
0.6
0.4
0.2
0
1000
2000
3000
4000
5000
6000
7000
8000
t
PWM2
1
0.8
0.6
0.4
0.2
0
1000
2000
3000
4000
5000
6000
7000
8000
PWM1 + PWM2
2
1.5
1
0.5
0
1000
2000
3000
4000
5000
6000
7000
8000

Fig4


L2
CH2
Lighting Controller
PWM2
S2a
LED Driv
Dr2
Decoding & Frame Detect
Decod
RDS
CLK2
D21
Clock Recovery
CI
Light 2 (Slave Device)
DMS
Com 2
D2n
Demodulation
Demod
10
S2
Als2
ALS Sensor
Photo Diode
L1
PWM1a
Dr1
LED Driver
Mod
Modulation
CS
Cod
Coding
Com1
Light 1 (Master Device)
CLK1
clk
data
DS
Ctl1
Lighting Controller
S1
Als1
D11
D1m
10

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2013/075126

A. CLASSIFICATION OF SUBJECT MATTER
INV. H05B33/08 H05B37/02
ADD.

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

B. FIELDS SEARCHED

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

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

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

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2007/121574 A1 (TIR SYSTEMS LTD [CA]; ASHDOWN IAN [CA]; LOVELAND DAMIEN [CA]; SPEIER I) 1 November 2007 (2007-11-01) abstract paragraphs [0011], [0038] - [0042] paragraphs [0052] - [0077] paragraphs [0082] - [0090] figures 2-7 -----	1-14
A	US 2012/310703 A1 (CAVALCANTI DAVE ALBERTO TAVARES [US] ET AL) 6 December 2012 (2012-12-06) paragraphs [0023] - [0060], [0091] - [0133] figures 1-7 -----	1-14

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

[X] See patent family annex.

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
14 March 2014	21/03/2014

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

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INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2013/075126

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2011/121761 A1 (ZHAO BIN [US]) 26 May 2011 (2011-05-26) paragraphs [0003], [0004], [0055], [0059] figures 1-9	1,10
A	WO 2012/146256 A2 (LIGHTEN APS [DK]; PEDERSEN STEEN HVIDTFELDT HESSELLUND [DK]) 1 November 2012 (2012-11-01) the whole document	1-14
A	US 5 193 201 A (TYMES LAROY [US]) 9 March 1993 (1993-03-09) column 1, line 45 - column 5, line 50 figures 1-6	1-14

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2013/075126

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		EP 2016807 A1	21-01-2009
		US 2009189530 A1	30-07-2009
		WO 2007121574 A1	01-11-2007
US 2012310703 A1	06-12-2012	NONE	
US 2011121761 A1	26-05-2011	NONE	
WO 2012146256 A2	01-11-2012	EP 2701801 A2	05-03-2014
		WO 2012146256 A2	01-11-2012
US 5193201 A	09-03-1993	NONE	