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(54) **CONTROL INTEGRATED CIRCUIT AND METHOD FOR CONTROLLING A CURRENT SOURCE CONFIGURED TO PROVIDE CURRENT TO LIGHTING MEANS, OPERATING DEVICE FOR LIGHTING MEANS, AND LUMINAIRE**

(57) The invention relates to control IC for controlling a current source configured to provide a current to lighting means optional at least one light emitting diode (LED). The control IC comprises a controller for controlling the current, a modulator for generating, based on an output of the controller, a periodically changing signal, wherein an amplitude of the signal periodically changes with a first frequency around an amplitude of the output of the controller, and a generator for generating, based on the periodically changing signal, a control signal for control-

ling the current source. The generator is configured to update the control signal according to a pulse signal having a second frequency greater than the first frequency. The generator is configured to provide the pulse signal to the modulator. The modulator is configured to update, based on the pulse signal, the amplitude of the signal so that the amplitude of the signal periodically changes in steps, with the first frequency, around the amplitude of the output of the controller.

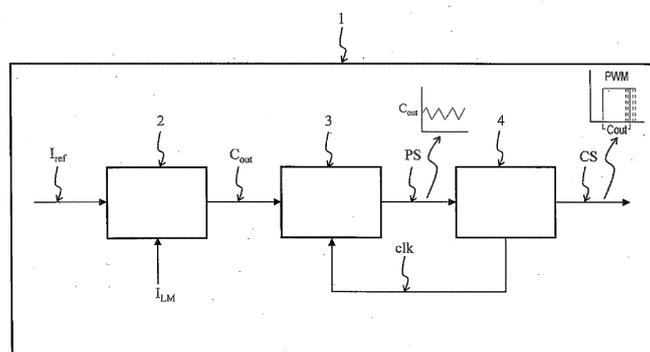


Figure 4

EP 4 231 783 A1

Description

[0001] The invention relates to a control integrated circuit (control IC) for controlling a current source configured to provide current to lighting means; an operating device for lighting means, the operating device comprising such a control IC; and a luminaire comprising such an operating device. Further, the invention relates to a method for controlling, by

a control IC, a current source configured to provide a current to lighting means.

[0002] Herein the term control integrated circuit is abbreviated by control IC.

[0003] For electrically supplying lighting means, such as light emitting diodes (LEDs), a current source may be used that is configured to provide a current to the lighting means. The current provided by the current source may be controlled by controlling the current source, i.e. controlling the operation of the current source. Such a current source may be referred to as controllable current source. Light emitted by the lighting means, i.e. a light emission of the lighting means, may be controlled by controlling the current and, thus, electrical energy provided to the lighting means. The greater the current, for example an average current over time, the greater the amount of light (e.g. light intensity) that is emitted by the lighting means and vice versa. The current control may be performed by a control IC.

[0004] For example, for controlling the current source, and, thus, the current provided by the current source a feedback control of the current may be performed with regard to a reference current (i.e. a reference quantity or reference value for the current). The reference current indicates the desired current to be provided by the current source to the lighting means in order to achieve a desired light emission by the lighting means.

[0005] Due to electromagnetic interference (EMI) the current provided to the lighting means may sporadically vary causing sudden flickering in the light emission of the lighting means that is visible to a person. This sudden flickering in the light emission of the lighting means is not wanted. For example, the EMI may be generated by operation of the current source (e.g. switching of a converter). In order to prevent such a sudden flickering caused by EMI, i.e. in order to mitigate the EMI, an output of the current control that is provided to a generator for generating a control signal for controlling the current source may be periodically changed with a frequency. As a result, the light emission is periodically changed around the desired light emission that is set by the output of the current control. Since this change of the light emission of the lighting means is periodical, it is less distractive for a person compared to a sudden flickering caused by EMI, as described above. The periodical change of the light emission may prevent the unwanted light flickering caused by EMI. The term "variation" may be used as a synonym for the term "change".

[0006] Preferably, the frequency of periodically changing the output of the current control is greater than a frequency that is visible to a person. That is, the frequency is above the visible light flicker spectrum. In other words, the frequency is set so that the output of the current control, which is periodically changed with the frequency, results in a control signal that causes a periodically changing current and, thus, a periodically changing light emission of the lighting means with the frequency, wherein the change of the light emission is not visible to a person.

[0007] Figure 1 shows a block diagram of an example of a control IC for controlling a current source configured to provide a current I_{LM} to lighting means. The control IC 1 of Figure 1 is configured to perform the above described control method for EMI mitigation. As shown in Figure 1, the control IC 1 may comprise a controller 2 (e.g. in the form of a PI controller) for controlling the current I_{LM} providable by the current source to the lighting means. As shown in Figure 1, the control IC 1 optionally may be configured to perform a feedback control of the current I_{LM} . For this, a reference current I_{ref1} for the current I_{LM} and a measurement of the current I_{LM} may be provided to the controller 2.

[0008] An output C_{out} of the controller 2 and, thus, of the current control (optionally feedback control) is provided to a modulator 3 of the control IC 1. The output C_{out} of the controller 2 may be referred as output of the current control performable by the controller 2. The output C_{out} may be referred to as output signal. The modulator 3 is configured to generate, based on the output C_{out} of the controller 2, a periodically changing signal PS, wherein an amplitude of the signal PS periodically changes with a first frequency around an amplitude of the output C_{out} of the controller 2. Thus, the modulator 3 is configured to modulate the output C_{out} of the controller 2 with the first frequency. As mentioned above, the first frequency is preferably above a frequency of light emission that is visible to a person, i.e. the human eye.

[0009] Next, the periodically changing signal PS is provided to a generator 4 (may be referred to as control signal generator) for generating a control signal CS, e.g. a pulse-width modulated (PWM) signal, for controlling the current source. The generator 4 is configured to generate, based on the periodically changing signal PS, the control signal CS. In case the control signal CS is a PWM signal, the duty cycle (i.e. ratio between on-time to period of signal) may periodically change with the first frequency with which the periodically changing signal PS periodically changes. Thus, the light emitted by the lighting means, electrically supplied with the current from the current source being controlled by the control signal CS, periodically changes with the aforementioned first frequency. Due to the modulation with the first frequency, EMI mitigation is achieved so that instead of sudden flickering in the light emission, the light emission is periodically changed on purpose. Preferably, this change of the light emission is with a frequency above the visible light spectrum.

[0010] Figure 2 shows a graph of an example of the periodically changing signal PS generated by the modulator 3 of the control IC 1 of Figure 1 and an example of pulse signals for the operation of the modulator 3 and the generator 4 of the control IC 1 of Figure 1. As shown in Figure 2, the modulator 3 of the control IC may be configured to generate, based

on the output C_{out} of the controller 2, the periodically changing signal PS such that the amplitude of the signal PS periodically changes in steps, with the first frequency, around the amplitude of the output C_{out} of the controller 2. In particular, the periodically changing signal PS may follow a triangular waveform around the amplitude of the output C_{out} of the controller 2. That is, the modulator 3 may generate the periodically changing signal PS by modulating, using e.g. a triangular signal or waveform having the first frequency, the output C_{out} of the controller 2 so that the amplitude of the signal PS periodically changes in steps, with the first frequency, around the amplitude of the output C_{out} of the controller 2. As a result, on average (i.e. on temporal average) the output C_{out} of the controller 2 is provided to the generator 4 (by providing the signal PS to the generator 4), wherein the generator 4 may generate the control signal CS, accordingly. In particular, the generator 4 may generate, based on the periodically changing signal PS, the control signal CS for controlling the current source (e.g. a switch of an actively switched converter), wherein the control signal CS is not constant due to the periodically changing signal PS, as outlined above. This results in EMI mitigation as explained above.

[0011] A drawback of the control method described above with regard to Figures 1 and 2 is that the time basis, on which the modulator 3 and the generator 4 of the control IC 1 operate or work, are not coordinated or synchronized. This is exemplarily shown in Figure 2. A pulse signal clk having a second frequency, on which the operation of the generator 4 is based, is exemplarily shown in the bottom graph of Figure 2, wherein the second frequency is greater than the first frequency (with which the signal PS periodically changes). In other words, the pulse signal clk with the second frequency is used for clocking the operation of the generator 4. For example, the generator 4 is configured to update the control signal CS according to the pulse signal clk having the second frequency. A second pulse signal clk_mod having a third frequency, on which the operation of the modulator 3 is based, is exemplarily shown in the middle graph of Figure 2, wherein the third frequency is greater than the first frequency. In other words, the second pulse signal clk_mod with the third frequency is used for clocking the operation of the modulator 3. For example, the modulator 3 is configured to update, based on the second pulse signal clk_mod , the amplitude of the signal PS so that the amplitude of the signal PS periodically changes in steps, with the first frequency, around the amplitude of the output C_{out} of the controller 2, as exemplarily shown in the top graph of Figure 2. In the graphs of Figure 2, the x-axis (horizontal axis) corresponds to the time (t).

[0012] The second frequency of the pulse signal clk (may be referred to as update frequency), according to which the generator 4 operates, may depend on or be equal to an operating frequency of the current source that is controlled by the control signal CS generated by the generator 4. Thus, the second frequency of the pulse signal clk may depend on the operating point of an operation of the current source. In contrast, the periodically changing signal PS periodically changes in steps with the first frequency, wherein the steps of the signal PS depend on or follow the second pulse signal clk_mod having the third frequency, wherein the second pulse signal clk_mod is independent from the pulse signal clk . That is, the third frequency is independent from the second frequency. For example, the second frequency of the pulse signal clk may be greater than the third frequency of the second pulse signal clk_mod , as exemplarily shown in Figure 2. As a result, the updates performable by the modulator 3 (i.e. the steps of the periodically changing signal PS) and the updates performable by the generator 4 may occur at different points in time, i.e. they may fall apart in time or they may asynchronously occur. This falling apart in time may usually change over time. This is exemplarily shown in **Figure 3** showing a magnification of a part of the graphs of Figure 2.

[0013] In the example shown in Figures 2 and 3, an update by the modulator 3 of the control IC 1 is triggered by a rising edge of the second pulse signal clk_mod (i.e. rising edge of pulses of the second pulse signal clk_mod) and an update by the generator 4 of the control IC 1 is triggered by a rising edge of the pulse signal clk (i.e. rising edge of pulses of the pulse signal clk). In Figure 3, a time period is exemplarily shown, during which two pulses of the second pulse signal clk_mod occur.

[0014] As shown in Figure 3, at a rising edge of a first pulse of the second pulse signal clk_mod , the modulator performs an update and, thus, a step of the periodically changing signal PS is generated or occurs. A rising edge of the pulse signal clk occurs with a first delay $D1$ (may be also referred to as first delay time) after the rising edge of the first pulse of the second pulse signal clk_mod , because the pulse signal clk and the second pulse signal clk_mod are not coordinated or synchronized. Thus, the generator 4 performs an update that is delayed by the first delay $D1$ after the update performed by the modulator 3 triggered by the first pulse of the pulse signal clk_mod . Therefore, from the perspective of the generator 4, the step of the periodically changing signal PS is generated later by the first delay $D1$ after the step of the periodically changing signal PS actually occurs or is actually generated. The periodically changing signal PS as seen from the perspective of the generator 4 is shown by the signal PS_gen in the third graph from the top.

[0015] As further shown in Figure 3, a second delay $D2$ between a rising edge of a second pulse of the second pulse signal clk_mod and a rising edge of the pulse signal clk is greater than the first delay $D1$. That is, as outlined already above, the falling apart in time between the pulse signal clk and the second pulse signal clk_mod may usually change over time.

[0016] The above described falling apart in time between the pulse signal clk (used for the operation of the generator 4) and the second pulse signal clk_mod (used for the operation of the modulator 3) may cause unwanted fluctuations of the light emission of the lighting means (electrically supplied by the current source controlled by the control IC 1). The

unwanted fluctuations of the light emission are visible in the light emission (e.g. visible light flickering). This may be due to the relative low frequency of the unwanted fluctuations. This unwanted fluctuations of the light emission may be referred to as beating or beats. Since the aforementioned unwanted fluctuations may be visible in the light emission, it is a drawback of the above described control method for EMI mitigation.

5 **[0017]** Therefore, it is an object of the invention to provide a control IC for controlling a current source configured to provide current to lighting means without the above described drawback. It is in particular an object of the invention to provide a control IC for controlling a current source configured to provide current to lighting means, which allows EMI mitigation while limiting or overcoming the occurrence of the aforementioned unwanted fluctuations (beating or beats) in the light emission of the lighting means.

10 **[0018]** These and other objects, which become apparent upon reading the following description, are solved by the subject-matter of the independent claims. The dependent claims refer to preferred embodiments of the invention.

[0019] According to a first aspect of the invention, a control integrated circuit (control IC) for controlling a current source is provided, wherein the current source is configured to provide a current to lighting means. Optionally, the lighting means are at least one light emitting diode (LED). The control IC comprises a controller for controlling the current. Further, the control IC comprises a modulator for generating, based on an output of the controller, a periodically changing signal. An amplitude of the signal periodically changes with a first frequency around an amplitude of the output of the controller. Furthermore, the control IC comprises a generator for generating, based on the periodically changing signal, a control signal for controlling the current source. The generator is configured to update the control signal according to a pulse signal having a second frequency that is greater than the first frequency. The generator is configured to provide the pulse signal to the modulator. The modulator is configured to update, based on the pulse signal, the amplitude of the signal so that the amplitude of the signal periodically changes in steps, with the first frequency, around the amplitude of the output of the controller.

15 **[0020]** In other words, the first aspect proposes to temporally coordinate or synchronize the operation of the modulator and the operation of the generator by providing the pulse signal, according to which the generator is configured to update the control signal, to the modulator. The modulator may thus update, based on the pulse signal, the amplitude of the periodically changing signal so that the amplitude of the signal periodically changes in steps, with the first frequency, around the amplitude of the output of the controller.

20 **[0021]** That is, the first aspect proposes to temporally coordinate or synchronize the update of the periodically changing signal performable by the modulator and, thus, the steps of the periodically changing signal with the update of the control signal performable by the generator. This eliminates or reduces the cause of the aforementioned disadvantageous unwanted fluctuations (i.e. beating or beats) in the light emission of the lighting means. For this, in contrast to the example described above with regard to Figures 1 to 3, according to the first aspect the generator may be configured to provide to the modulator the pulse signal with the second frequency, according to which the generator is configured to update the control signal. The modulator is configured to update, based on the pulse signal received from the generator, the amplitude of the periodically changing signal. Thus, for the operation of the modulator a second pulse signal being independent of the pulse signal is not anymore used, as it is the case in the example described above with regard to Figure 1 to 3. In other words, the pulse signal received from the generator may be used as a pulse generator for the update of the amplitude of the periodically changing signal that is performable by the modulator. The passage "update of the periodically changing signal" and "update of the amplitude of the periodically changing signal" may be used as synonyms. That is, the pulse signal received from the generator may be used for clocking the operation of the modulator and, thus, the update of the amplitude of the periodically changing signal by the modulator. Due to signal processing a temporal offset (such as for example the delay time D1 shown in Figure 2) between the updates performable by the modulator or the edges of the steps of the periodically changing signal and the updates performable by the generator may still occur. However, due to the above-described temporal synchronization based on providing the pulse signal from the generator to the modulator, such a possible temporal offset is constant. As a result, no unwanted fluctuations (i.e. beating or beats) visible in the light emission of the lighting means are caused by the aforementioned possible temporal offset. Therefore, the control IC according to the first aspect does not have the disadvantageous visible effect on the light emission of the lighting means, as exemplarily described above with regard to Figures 1 to 3. Therefore, the control IC according to the first aspect solves at least the above indicated objects.

25 **[0022]** Controlling the current source may be understood as controlling the current provided by the current source. For the control of the current, a measurement of the current may be provided to the controller. That is, the controller may be configured to receive a measurement of the current. The controller may be configured to perform, based on a reference current, a feedback control of the current. The term "closed-loop control" may be used as a synonym for the term "feedback control". The controller may be configured to perform the feedback control by computing an error between a measurement of the current and the reference current and generating or computing, based on the error, an output (may be referred to as control output). In addition or alternatively, the controller may be configured to perform a feedforward control of the current. The term "open-loop control" may be used as a synonym for the term "feedforward control".

30 **[0023]** Optionally, the controller is or comprises a P controller, a PI controller, a PID controller or any combination

thereof. Additionally or alternatively, the controller may be or may comprise any other controller type known in the art. The output of the controller may be indicative of a value of the current.

[0024] Optionally, the control signal is a pulse-width modulated signal (PWM signal).

[0025] As mentioned above, the modulator is configured to update, based on the pulse signal, the amplitude of the signal so that the amplitude of the signal periodically changes in steps, with the first frequency, around the amplitude of the output of the controller. In other words, the periodically changing signal comprises steps, wherein the modulator may be configured to generate the steps by updating the amplitude of the periodically changing signal. That is, the amplitude of each step of the periodically changing signal may correspond to a respective updated value of the amplitude.

[0026] The first frequency of the periodically changing signal may be greater than a frequency visible to a person, i.e. the human eye. That is, the first frequency may be greater than the visible light flicker spectrum. In other words, the frequency may be set so that a change of light with the first frequency is not visible to a person, i.e. the human eye.

[0027] The pulse signal may be understood as a signal comprising a periodically occurring pulse with a pulse frequency (the pulse frequency may be referred to as second frequency). The pulse signal may be referred to as a clock signal, which is a signal used for clocking the update, (performable by the generator) of the control signal. The pulse signal may be generated based on a system clock of the generator.

[0028] The passage "updating based on the pulse signal" may be understood as "updating depend on the pulse signal" or "updating according to the pulse signal".

[0029] For example, the control IC may be an application specific integrated circuit (ASIC) or a field-programmable gate array (FPGA).

[0030] The modulator may be configured to generate the periodically changing signal such that the amplitude of the signal periodically changes in steps, with the first frequency, wherein the periodically changing signal follows a triangular waveform around the amplitude of the output of the controller.

[0031] In other words, the periodically changing signal may comprise steps, wherein the modulator may be configured to generate the steps by updating the amplitude of the periodically changing signal according to a triangular waveform that periodically changes with the first frequency. That is, the amplitude of each step of the periodically changing signal may correspond to a respective amplitude of a triangular waveform periodically changing, with the first frequency, around the amplitude of the output of the controller. Therefore, the modulator may be configured to modulate the output of the controller using the triangular waveform periodically changing with the first frequency.

[0032] The triangular waveform is only optional and, thus, another waveform type may be used, such as a sinus waveform, a sawtooth waveform etc.

[0033] The generator may be configured to update the control signal at a rising edge or falling edge of the pulse signal. The modulator may be configured to update the periodically changing signal (amplitude of the periodically changing signal) at a rising edge or falling edge of the pulse signal.

[0034] The second frequency may depend on the operating point of an operation of the current source.

[0035] In other words, the second frequency may depend on an operating frequency of the current source. Optionally, the greater an operating frequency of the current source the greater may be the second frequency and vice versa. Optionally, the second frequency is equal to the operating frequency of the current source.

[0036] The current source may comprise or may be an actively switched DC/DC converter comprising at least one switch controllable for controlling the current providable by the current source to the lighting means, and the second frequency may depend on the operating point of an operation of the actively switched DC/DC converter.

[0037] Examples of an actively switched DC/DC converter comprise a buck-converter, boost-converter, buck-boost-converter, flyback converter, resonance converter etc. The term "actively clocked DC/DC converter" may be used as a synonym for the term "actively switched DC/DC converter". The at least one switch may be or may comprise one or more transistors. Examples of transistors comprise field-effect transistors (FETs), e.g. metal-oxide semiconductor FETs (MOSFETs); bipolar junction transistors (BJTs); insulated gate bipolar transistors (IGBTs) etc.

[0038] The generator may be configured to generate, based on the periodically changing signal, the control signal for controlling the at least one switch of the actively switched DC/DC converter. The second frequency may be equal to a switching frequency for switching the at least one switch.

[0039] The greater the switching frequency of the at least one switch of the actively switched DC/DC converter the greater may be the second frequency and vice versa.

[0040] Optionally, the modulator is configured to update, every period of the pulse signal, the amplitude of the signal.

[0041] The modulator may be configured to update the amplitude of the signal at a rising edge or falling edge of the pulse signal. In other words the modulator may be configured to update, every pulse or cycle of the pulse signal, the amplitude of the signal.

[0042] Optionally, the modulator is configured to scale down the pulse signal received from the generator using a scale n , wherein n is a positive integer greater than or equal to two ($n \geq 2$). The modulator may be configured to update, every n -th period of the pulse signal, the amplitude of the signal.

[0043] In other words the modulator may be configured to update, every n -th pulse or n -th cycle of the pulse signal,

the amplitude of the signal. The modulator may be configured to update every n-th period of the pulse signal the amplitude of the signal at a rising edge or falling edge of the pulse signal.

[0044] The scale n allows a variable relationship or ratio between the pulse signal provided from the generator 4 and a clocking or temporal control of the update of the amplitude of the periodically changing signal performable by the modulator.

[0045] The scale n may depend on the second frequency of the pulse signal.

[0046] The greater the second frequency of the pulse signal the greater may be the scale n and vice versa. Since the second frequency of the pulse signal may depend on the operating point of an operation of the current source, the scale n may depend on the operating point of the operation of the current source.

[0047] The current source may comprises or may be an actively switched DC/DC converter comprising at least one switch controllable for controlling the current providable by the current source to the lighting means, and the scale n may depend on the operating point of an operation of the actively switched DC/DC converter.

[0048] The greater a switching frequency for switching the at least one switch of the actively switched DC/DC converter the greater may be the second frequency and vice versa. The greater the switching frequency for switching the at least one switch of the actively switched DC/DC converter the greater may be the scale n and vice versa. The switching frequency is an example of the operating frequency of the current source. In case the control signal, which may be generated by the generator of the control IC, is a PWM signal, the frequency of the PWM signal may depend on or may be equal to the switching frequency for switching the at least one switch of the actively switched DC/DC converter.

[0049] Optionally, the control IC is configured to obtain the scale n from a look-up table.

[0050] The look-up table may be stored in a storage associated or being part of the control IC.

[0051] Optionally, the control IC is configured to obtain the scale n from outside the control IC. For example, the control IC may be configured to obtain the scale n from a microcontroller.

[0052] In order to achieve the control IC according to the first aspect of the invention, some or all of the above-described optional features may be combined with each other.

[0053] According to a second aspect of the invention, an operating device for lighting means is provided. Optionally, the lighting means are at least one light emitting diode (LED). The operating device comprises a current source configured to provide a current to the lighting means, and a control IC according to the first aspect, as described above. The control IC is configured to control the current source.

[0054] In case the operating device is for LEDs, the term "LED-driver" may be used as a synonym for the term "operating device". The operating device may be a ballast for lighting means, such as at least one LED.

[0055] Optionally, the current source comprises or is an actively switched DC/DC converter comprising at least one switch controllable for controlling the current providable by the current source to the lighting means. The second frequency may depend on the operating point of an operation of the actively switched DC/DC converter.

[0056] The control IC may be configured to control the current providable by the current source to the lighting means by controlling switching of the at least switch of the actively switched DC/DC converter. The control IC may be configured to control switching of the at least one switch of the actively switched DC/DC converter by providing the control signal, which may be generated by the generator of the control IC, to the at least one switch. The generator may be configured to generate, based on the periodically changing signal, the control signal for controlling the at least one switch of the actively switched DC/DC converter.

[0057] The second frequency of the pulse signal may equal to a switching frequency for switching the at least one switch.

[0058] Examples of an actively switched DC/DC converter comprise a buck-converter, boost-converter, buck-boost-converter, flyback converter, resonance converter etc. The at least one switch may be or may comprise one or more transistors. Examples of transistors comprise field-effect transistors (FETs), e.g. metal-oxide semiconductor FETs (MOS-FETs); bipolar junction transistors (BJTs); insulated gate bipolar transistors (IGBTs) etc.

[0059] Optionally, the greater a switching frequency of the at least one switch of the actively switched DC/DC converter the greater the second frequency and vice versa.

[0060] Optionally, the current source comprises or is an actively switched DC/DC converter comprising at least one switch controllable for controlling the current providable by the current source to the lighting means, and the scale n depends on the operating point of an operation of the actively switched DC/DC converter.

[0061] The greater a switching frequency for switching the at least one switch of the actively switched DC/DC converter the greater may be the second frequency and vice versa.

[0062] Optionally, the greater a switching frequency for switching the at least one switch of the actively switched DC/DC converter the greater the scale n and vice versa.

[0063] The switching frequency is an example of the operating frequency of the current source. In case the control signal, which may be generated by the generator of the control IC, is a PWM signal, the frequency of the PWM signal may depend on or may be equal to the switching frequency for switching the at least one switch of the actively switched DC/DC converter.

[0064] Optionally, the operating device may comprise a microcontroller. The control IC may be configured to obtain

the scale n from the microcontroller. The microcontroller and control IC may be configured to form a control system of the operating device.

5 [0065] Optionally, the operating device comprises a communication interface for communication to outside the operating device. The control IC may be configured to obtain via the communication interface the scale n. For example, the optional microcontroller of the operating device may be configured to obtain via the communication interface information from outside the operating device (e.g. the scale n). The microcontroller may be configured to provide the obtained information (e.g. the scale n) to the control IC.

10 [0066] The communication interface may be configured to communicate wirelessly and/or wire bound. The communication interface may comprise or may be a bus interface configured for being electrically connected to a bus. The bus may be a wired bus. The bus may be a DALI-bus or DALI-2 bus, i.e. a bus according to the DALI ("Digital Addressable Lighting Interface") standard or DALI-2 standard. They are well known standards in the field of lighting, wherein DALI-2 is the follow up standard of DALI. The bus may any other known bus type, such as a Distributed Systems Interface (DSI) bus. Thus, the communication interface may comprise or may be a DALI interface, a DALI-2 interface, a DSI interface etc.

15 [0067] The communication interface may be configured to be electrically connected to a memory or data storage, e.g. a secure digital memory card (SD card), universal serial bus (USB) flash drive (e.g. USB stick) etc. Thus, the communication interface may comprise or may be a SD interface, USB interface etc.

20 [0068] The above description with regard to the control IC according to the first aspect of the invention is also valid for the operating device according to the second aspect of the invention. The above description with regard to the operating device according to the second aspect of the invention may be valid for the control IC according to the first aspect.

[0069] The operating device according to the second aspect of the invention achieves the same advantages as the control IC according to the first aspect of the invention.

[0070] In order to achieve the operating device according to the second aspect of the invention, some or all of the above-described optional features may be combined with each other.

25 [0071] According to a third aspect of the invention a luminaire is provided. The luminaire comprises an operating device according to the second aspect, as described above, and lighting means. Optionally, the lighting means are at least one light emitting diode (LED). The operating device is configured to operate the lighting means.

30 [0072] The lighting means may comprise or be one or more lighting elements. The lighting means are not limited to being at least one LED (i.e. one or more LEDs) and, thus, may additionally or alternatively be at least one other lighting means type.

[0073] The above description with regard to the operating device according to the second aspect of the invention is also valid for the luminaire according to the third aspect of the invention.

[0074] The luminaire according to the third aspect of the invention achieves the same advantages as the control IC according to the first aspect of the invention.

35 [0075] According to a fourth aspect of the invention, a method for controlling, by a control IC, a current source configured to provide a current to lighting means is provided. Optionally, the lighting means are at least one light emitting diode (LED). The control IC comprises a controller for controlling the current. Further, the control IC comprises a modulator for generating, based on an output of the controller, a periodically changing signal, wherein an amplitude of the signal periodically changes with a first frequency around an amplitude of the output of the controller. Furthermore, the control IC comprises a generator for generating, based on the periodically changing signal, a control signal for controlling the current source. The method comprises updating, by the generator, the control signal according to a pulse signal having a second frequency that is greater than the first frequency. Further, the method comprises providing, by the generator, the pulse signal to the modulator. Furthermore, the method comprises updating, by the modulator, based on the pulse signal the amplitude of the signal so that the amplitude of the signal periodically changes in steps, with the first frequency, around the amplitude of the output of the controller.

45 [0076] The above description with regard to the control IC according to the first aspect of the invention is also valid for the method according to the fourth aspect of the invention. The control IC may be a control IC according to the first aspect.

50 [0077] The method may comprise generating, by the modulator, the periodically changing signal such that the amplitude of the signal periodically changes in steps, with the first frequency, wherein the periodically changing signal follows a triangular waveform around the amplitude of the output of the controller.

[0078] The second frequency may depend on the operating point of an operation of the current source.

55 [0079] Optionally, the method comprises updating, by the modulator, every period of the pulse signal the amplitude of the signal. That is, the modulator may update the amplitude of the periodically changing signal every period of the pulse signal.

[0080] Optionally, the method comprises scaling down, by the modulator, the pulse signal received from the generator using a scale n, wherein n is a positive integer greater than or equal to two ($n \geq 2$). The method may comprise updating, by the modulator, every n-th period of the pulse signal the amplitude of the signal. That is, the modulator may update

the amplitude of the signal every n-th period of the pulse signal.

[0081] The scale n may depend on the second frequency of the pulse signal.

[0082] Optionally, the method comprises obtaining, by the control IC, the scale n from a look-up table.

[0083] Optionally, the method comprises obtaining, by the control IC, the scale n from outside the control IC. For example, the method may comprise obtaining, by the control IC, the scale n from a microcontroller.

[0084] The method according to the fourth aspect of the invention achieves the same advantages as the control IC according to the first aspect of the invention.

[0085] In order to achieve the method according to the fourth aspect of the invention, some or all of the above-described optional features may be combined with each other.

[0086] It has to be noted that all devices, elements, units and means described in the present application could be implemented in software or hardware elements or any kind of combination thereof. All steps which are performed by the various entities described in the present application as well as the functionalities described to be performed by the various entities are intended to mean that the respective entity is adapted to or configured to perform the respective steps and functionalities.

[0087] In the following, the invention is described exemplarily with reference to the enclosed Figures, in which

Figure 1 shows a block diagram of an example of a control integrated circuit (control IC) for controlling a current source configured to provide a current to lighting means;

Figure 2 shows a graph of an example of a periodically changing signal generated by a modulator of the control IC of Figure 1 and an example of pulse signals for the operation of the modulator and a generator of the control IC of Figure 1;

Figure 3 shows a magnification of a part of the graphs of Figure 2; and

Figure 4 shows a block diagram of a control IC according to an embodiment of the invention for controlling a current source configured to provide a current to lighting means;

Figures 5 (A) and (B) each show a graph of an example of a periodically changing signal generated by a modulator of the control IC of Figure 4 and an example of a pulse signal received by the modulator from a generator of the control IC of Figure 4; and

Figure 6 shows a block diagram of a luminaire according to an embodiment of the invention.

[0088] In the Figures, corresponding elements have the same reference signs.

[0089] **Figure 4** shows a block diagram of a control IC according to an embodiment of the invention for controlling a current source configured to provide a current to lighting means. In particular, Figure 2 shows an example of the control IC according to the first aspect of the invention, as described above.

[0090] The control IC 1 of Figure 4 is a control IC for controlling a current source, wherein the current source is configured to provide a current I_{LM} to lighting means, such as one or more LEDs. As shown in Figure 4, the control IC 1 comprises a controller 2 for controlling the current I_{LM} . The controller 2 may be implemented by software and/or hardware. Optionally, the controller 2 may be configured to perform, based on a reference current I_{ref} , a feedback control of the current I_{LM} (as exemplarily indicated in Figure 4). In addition or alternatively, the control IC 1 may be configured to perform a feedforward control of the current I_{LM} .

[0091] Further, the control IC 1 comprises a modulator 3. The controller 2 may be configured to provide its output C_{out} to the modulator 3. The modulator 3 may be configured to generate, based on the output C_{out} of the controller 2, a periodically changing signal PS, wherein an amplitude of the signal PS periodically changes with a first frequency around an amplitude of the output C_{out} of the controller 2. The output C_{out} may be referred to as signal C_{out} (output signal) that is output by the controller 2. The modulator 3 may be implemented by software and/or hardware. The modulator 3 may be configured to generate the periodically changing signal PS having the first frequency by amplitude modulating the output C_{out} of the controller 2 with a waveform having an amplitude periodically changing with the first frequency.

[0092] As exemplarily shown in Figure 4, the waveform may be optionally a triangular waveform. That is, the modulator 3 may be configured to generate, based on the output C_{out} of the controller 2, the periodically changing signal PS such that the amplitude of the signal PS periodically changes, with the first frequency, around the amplitude of the output C_{out} of the controller 2 according to a triangular waveform. This is indicated in Figure 4. The waveform for modulating the output C_{out} of the controller 2 is not limited to a triangular waveform and may be any other periodically changing waveform, such as a sinus waveform.

[0093] Furthermore, the control IC comprises a generator 4. The modulator 3 may be configured to provide the peri-

odically changing signal PS to the generator 4. The generator 4 may be implemented by software and/or hardware. The generator 4 may be configured to generate, based on the periodically changing signal PS, a control signal CS (e.g. a PWM signal) for controlling the current source. The generator 4 may be configured to update the control signal CS according to a pulse signal clk having a second frequency that is greater than the first frequency. As shown in Figure 4, the generator 4 may be configured to provide the pulse signal clk to the modulator 3. The modulator 3 may be configured to update, based on or depended on the pulse signal clk, the amplitude of the signal PS so that the amplitude of the signal PS periodically changes in steps, with the first frequency, around the amplitude of the output C_{out} of the controller 2. In other words, the operation of the modulator 3 and the operation of the generator 4 may be temporally coordinated or synchronized with each other via the pulse signal clk.

[0094] The output C_{out} of the controller 2 may determine the switching characteristic of the generator 4. Optionally, the current source comprises or is an actively switched DC/DC converter with at least one switch, wherein the at least one switch is controlled by the control signal CS generated by the generator 4. In this case, for controlling the current providable by the actively switched DC/DC converter, a peak control or an on-time control of the at least one switch may be performed by providing the control signal CS to the at least one switch. For example, a peak control may comprise switching, optionally turning-off, the at least one switch when the current I_{LM} reaches a peak value. For example, an on-time control may comprise switching, optionally turning-off, the at least one switch when a time indicating the on-time has elapsed.

[0095] The first frequency of the periodically changing signal PS may be greater than a frequency visible to a person, i.e. the human eye. That is, the first frequency may be greater than the visible light flicker spectrum. In other words, the frequency may be set so that a change of light with the first frequency is not visible to a person, i.e. the human eye.

[0096] Therefore, the first frequency of the periodically changing signal PS may be set such that the influence of the periodically changing signal PS on the current I_{LM} providable by the current source to the lighting means, when the current source is controlled by the control IC 1, does not result in a visible change or fluctuation of the light emission of the lighting means. This allows an efficient improvement of EMI mitigation. The first frequency may be referred to as sweep frequency. Optionally, the first frequency is not increased above an upper border frequency. The term "upper frequency threshold" may be used as a synonym for the term "upper border frequency". The upper border frequency may be selected such that the positive effect of the generation, by the modulator 3, of the periodically changing signal PS (i.e. of the modulation, by the modulator 3, of the output C_{out} of the controller 2) on improving EMI mitigation is sufficiently large or great. This selection may be empirically obtained. The positive effect on improving EMI mitigation may decrease as the first frequency increases and vice versa.

[0097] Optionally, the second frequency of the pulse signal clk depends on the operating point of an operation of the current source. In other words, the second frequency may depend on an operating frequency of the current source. Optionally, the greater an operating frequency of the current source the greater may be the second frequency and vice versa.

[0098] The modulator 3 may be configured to update, every period of the pulse signal clk, the amplitude of the signal PS. This is exemplarily shown in Figure 5 (A).

[0099] Optionally, the modulator 3 is configured to scale down the pulse signal clk received from the generator 4 using a scale n , wherein the scale n is a positive integer greater than or equal to two ($n \geq 2$). The modulator 3 may be configured to update, every n -th period of the pulse signal clk, the amplitude of the signal PS. This is exemplarily shown in Figure 5 (B), wherein in the example of Figure 5 (B) the scale n is equal to two ($n = 2$). This is only by way of example, not limiting the present disclosure.

[0100] The control IC 1 may be configured to obtain the scale n from a look-up table (not shown in Figure 4). The control IC 1 may comprise a storage, in which the look-up table is stored. Alternatively or additional, the control IC 1 may be associated with a storage, in which the look-up table is stored.

[0101] The control IC 1 may be configured to obtain the scale n from outside the control IC 1 (not shown in Figure 4). Optionally, the control IC 1 is configured to obtain the scale n from a microcontroller.

[0102] The scale n may depend on the second frequency of the pulse signal clk. Optionally, the greater the second frequency of the pulse signal clk the greater is the scale n and vice versa. Since the second frequency of the pulse signal clk may depend on the operating point of an operation of the current source, the scale n may depend on the operating point of the operation of the current source. Thus, optionally, the greater an operating frequency of the current source the greater may be the scale n and vice versa.

[0103] The current source may comprise or may be an actively switched DC/DC converter comprising at least one switch controllable for controlling the current providable by the current source to the lighting means.

[0104] The second frequency of the pulse signal clk may depend on the operating point of an operation of the actively switched DC/DC converter. The second frequency of the pulse signal clk may equal to the switching frequency for switching the at least one switch.

[0105] The generator 4 of the control IC1 may be configured to generate, based on the periodically changing signal PS, the control signal CS for controlling the at least one switch of the actively switched DC/DC converter. The switching

frequency is an example of the operating frequency of the current source. In case the control signal CS is a PWM signal, the frequency of the PWM signal may depend on or may be equal to the switching frequency for switching the at least one switch of the actively switched DC/DC converter.

5 **[0106]** The greater the switching frequency of the at least one switch of the actively switched DC/DC converter the greater may be the second frequency of the pulse signal clk and vice versa. The greater the switching frequency for switching the at least one switch of the actively switched DC/DC converter the greater may be the scale n and vice versa.

10 **[0107]** The switching frequency of the at least one switch of the actively switched DC/DC converter may be depend on the operation point of the converter, e.g. on an operation point for achieving a dimming level of the light emission of the lighting means. This may result in a case, in which the first frequency of the periodically changing signal PS may reach, when the switching frequency is high, a frequency range that is not sufficient for improving EMI mitigation. At low switching frequencies, it is preferable that the first frequency of the periodically changing signal PS does not cause visible fluctuations of the light emission of the lighting means. Therefore, it is preferable to keep the first frequency in a target range, which may be empirically obtained. For this, the above-described embodiment may be implemented, according to which the modulator 3 may be configured to scale down the pulse signal clk received from the generator 4 using a scale n. The scale n may be also referred to as a divider.

15 **[0108]** The scale n allows a variable relationship or ratio between the pulse signal clk provided from the generator 4 to the modulator 3 and a clocking or temporal control of the update of the amplitude of the periodically changing signal PS performable by the modulator 3.

20 **[0109]** The functions of the control IC 1 described above may be implemented by software and/or hardware. Thus, the controller 2, modulator 3 and the generator 4 may be implemented by software and/or hardware.

[0110] For further details of the control IC of Figure 4 reference is made to the above description of the control IC according to the first aspect.

25 **[0111] Figures 5 (A) and (B)** each show a graph of an example of a periodically changing signal generated by a modulator of the control IC of Figure 4 and an example of a pulse signal received by the modulator from a generator of the control IC of Figure 4. For describing the Figures 5 (A) and 5 (B) reference is made to Figure 4.

[0112] The triangular waveform of the signal PS in the graphs 5 (A) and 5 (B) is only by way of example and is not limiting the present disclosure. That is, the signal PS may periodically change, with the first frequency, according to a different waveform, e.g. a sinus waveform. As shown in Figures 5 (A) and 5 (B) the signal PS periodically changes in steps, i.e. the signal PS comprises steps.

30 **[0113]** As shown in Figure 5 (A), the modulator 3 may be configured to update, every period of the pulse signal clk received from the generator 4, the amplitude of the signal PS. According to the embodiment of Figure 5 (A), the modulator 3 is configured to update the amplitude of the signal PS at every rising edge of the pulse signal clk. As a result, at every rising edge of the pulse signal clk, a new step of the signal PS occurs or is generated. This is only by way of example and does not limit the present disclosure. For example, the update may occur at every falling edge of the pulse signal clk.

35 **[0114]** As shown in Figure 5 (B), the modulator 3 may be configured to scale down the pulse signal clk received from the generator 4 using a scale n, the scale n being a positive integer greater than or equal to two ($n \geq 2$). The modulator 3 may be configured to update, every n-th period of the pulse signal clk, the amplitude of the signal PS. In the case of Figure 5 (B), the scale n is equal to two ($n = 2$) and, thus, the modulator 3 may be configured to update, every second period or second pulse of the pulse signal clk, the amplitude of the signal PS. The scale n equaling to two ($n = 2$) is only by way of example and does not limit the present disclosure.

40 **[0115]** According to the embodiment of Figure 5 (B), the modulator 3 is configured to update the amplitude of the signal PS at a rising edge of every second period or pulse of the pulse signal clk. As a result, at every second rising edge of the pulse signal clk, a new step of the signal PS occurs or is generated. This is only by way of example and does not limit the present disclosure. For example, the update may occur at every second falling edge of the pulse signal clk.

45 **[0116]** As shown in Figure 5, the modulator 3 may be configured to generate the periodically changing signal PS having the first frequency synchronized, via the pulse signal clk, with the operation of the generator 4, while the signal PS, in particular its first frequency, is not effected or influenced by a change of the second frequency of the pulse signal clk. Namely, the second frequency of the pulse signal clk of Figure 5 (B) is greater than the second frequency of the pulse signal clk of Figure 5 (A), whereas the signal PS is the same for both Figures 5 (A) and 5 (B).

50 **[0117]** For further information on Figures 5 (A) and 5 (B) reference is made to the above description of the control IC according to the first aspect and the description of the control IC of Figure 4.

[0118] Figure 6 shows a block diagram of a luminaire according to an embodiment of the invention. The luminaire is an example of a luminaire according to the third aspect. Thus, the description with regard to the luminaire according to the third aspect is correspondingly valid for the luminaire of Figure 6.

55 **[0119]** As shown in Figure 6, the luminaire 14 comprises an operating device 13 and lighting means 8, wherein the operating device is configured to operate the lighting means 8. The lighting means 8 may be one or more LEDs (i.e. at least one LED), as exemplarily shown in Figure 6. The lighting means 8 may be alternatively or additionally any other

lighting means type. The operating device 13 is an example of the operating device according to the second aspect. Thus, the description with regard to the operating device according to the second aspect is correspondingly valid for the operating device 13.

[0120] As shown in Figure 6, the operating device 13 comprises a current source 7 configured to provide a current I_{LM} to the lighting means 8, and a control IC 1, wherein the control IC 1 is configured to control the current source 7 and, thus, control the current I_{LM} providable by the current source 7. The control IC 1 is an example of the control IC of the first aspect. Thus, the above description with regard to the control IC according to the first aspect and the control IC of Figure 4 as well as the description of Figures 5 (A) and 5 (B) are correspondingly valid for the control IC 1. The control IC 1 may be an ASIC or an FPGA. The operating device 13 may optionally comprise a microcontroller 5. The control IC 1 and the microcontroller 5 may form a control system.

[0121] The control IC 1 may be configured to control the current source 7 by providing a control signal CS to the current source 7. Optionally, the current source 7 may be an actively switched DC/DC converter with at least one switch, and the control IC 1 is configured to control switching of the at least one switch. Optionally, the control IC 1 may be configured to control switching of the at least one switch by providing the control signal CS to the switch.

[0122] Examples of an actively switched DC/DC converter comprise a buck-converter, boost-converter, buck-boost-converter, flyback converter, resonance converter etc. The at least one switch may be or may comprise one or more transistors. Examples of transistors comprise field-effect transistors (FETs), e.g. metal-oxide semiconductor FETs (MOS-FETs); bipolar junction transistors (BJTs); insulated gate bipolar transistors (IGBTs) etc.

[0123] The operating device 13 may comprise a measurement unit for measuring the current I_{LM} providable by the current source 7 (not shown in Figure 6). The measurement unit may comprise or may be a shunt resistor. The control IC 1 may be configured to obtain the measurement of the current I_{LM} and use it for a control (e.g. feedback control and/or feedforward control) of the current I_{LM} .

[0124] Optionally, the operating device 13 may comprise a power factor control (PFC) and/or filter circuit 6. This PFC and/or filter circuit 6 may comprise an actively switched converter (e.g. AC/DC converter and/or DC/DC converter) for performing the PFC function, filter means (e.g. EMI filter) and/or rectifier means. The PFC and/or filter circuit 6 may be implemented in any way known in the art. Optionally, there may be additional converter stages before the current source 7 (not shown), so that the optional PFC and/or filter circuit 6, the optional one or more additional converter stages, and the current source 7 form an electrical energy supply circuit for providing electrical energy from an external electrical energy source 15, e.g. mains, to the lighting means 8. Thus, the current source 7 may be electrically supplied, e.g. provided with a DC voltage, from the optional PFC and/or filter circuit 6 or a converter stage of the optional one or more additional converter stages. The optional one or more additional converter stages may be electrically supplied from the external electrical energy source 15 (in case the optional PFC and/or filter circuit 6 is not present) or from the optional PFC and/or filter circuit 6. The optional PFC and/or filter circuit 6 may be electrically supplied from the external electrical energy source 15.

[0125] The optional PFC and/or filter circuit 6 may be controlled by the control IC 1, as indicated in Figure 6. The optional one or more converter stages may be controlled by the control IC 1.

[0126] The operating device 13 may comprise a communication interface 11 for communication to outside the operating device 13. The microcontroller 5 may be configured to obtain via the communication interface 11 information (e.g. the scale n for optionally scaling down, by the modulator of the control IC, the pulse signal clk) from outside the operating device 13. The microcontroller 5 may be configured to provide the information, obtained via the communication interface 11, to the control IC 1. Optionally, outside the operating device 13 may mean outside the luminaire 14. Optionally, the microcontroller 5 may be configured to obtain via the communication interface 11 information regarding the scale n and generate or compute based on said information the scale n .

[0127] The microcontroller 5 may be configured to provide information, e.g. the scale n , to the control IC 1. The control IC 1 may be configured to obtain the scale n from a look-up table. The look-up table may be stored in a storage of the control IC and/or a storage associated with the control IC 1.

[0128] The communication interface 11 may be configured to communicate wirelessly and/or wire bound. The communication interface 11 may comprise or may be a bus interface configured for being electrically connected to a bus 10. The bus 10 may be a wired bus. The bus 10 may be a DALI-bus or DALI-2 bus, i.e. a bus according to the DALI ("*Digital Addressable Lighting Interface*") standard or DALI-2 standard. The bus 10 may be any other known bus type, such as a Distributed Systems Interface (DSI) bus. Thus, the communication interface 11 may comprise or may be a DALI interface, a DALI-2 interface, a DSI interface etc. The bus 10 may be part of the luminaire 14. The communication interface 11 may be configured to be electrically connected to a memory or data storage, e.g. a secure digital memory card (SD card), universal serial bus (USB) flash drive (e.g. USB stick) etc. Thus, the communication interface 11 may comprise or may be a SD interface, USB interface etc.

[0129] As shown in Figure 6, the microcontroller 5 may optionally be electrically connected to the communication interface 11 via a galvanic isolation circuit 12. For example, the isolation circuit 12 may comprise one or more optocouplers, one or more transformers etc. The microcontroller 5 may be configured to communicate via the communication interface

11 with outside the operating device 13, i.e. with an external unit outside the operating device 13. Outside the operating device 13 may optionally mean outside the luminaire 14. The microcontroller 5 may be configured to store the scale n . A user may provide, for example via the communication interface 11, the scale n to the microcontroller 5. The microcontroller 5 may be configured to provide the obtained scale n to the control IC 1.

[0130] Optionally, the operating device 13 may comprise a low voltage power supply 9 for electrically supplying the control IC 1, the microcontroller 5, and the communication interface 11. The low voltage power supply 9 may be electrically supplied from the external electrical energy source 15. For example, as exemplarily shown in Figure 6, the low voltage power supply 9 may be electrically supplied, e.g. with a voltage, from the optional PFC and/or filter circuit 6.

[0131] For describing the function of the control IC 1 and, thus, the control of the current source 7 reference is made to the above description with regard to the control IC according to the first aspect and the description with regard to Figures 4, 5 (A) and 5 (B).

[0132] For further details of the luminaire 14 of Figure 6 reference is made to the above description of the luminaire according to the third aspect. For further details of the operating device 13 of Figure 6 reference is made to the above description of the operating device according to the second aspect.

[0133] In the claims as well as in the description the word "comprising" does not exclude other elements or steps and the indefinite article "a" or "an" does not exclude a plurality. A single element or other unit may fulfill the functions of several entities or items recited in the claims. The mere fact that certain measures are recited in the mutual different dependent claims does not indicate that a combination of these measures cannot be used in an advantageous implementation.

Claims

1. A control integrated circuit (1), control IC, for controlling a current source (7) configured to provide a current (I_{LM}) to lighting means (8), optional at least one light emitting diode, LED; wherein the control IC (1) comprises

- a controller (2) for controlling the current (I_{LM}),
- a modulator (3) for generating, based on an output (C_{out}) of the controller (2), a periodically changing signal (PS), wherein an amplitude of the signal (PS) periodically changes with a first frequency around an amplitude of the output (C_{out}) of the controller (2), and
- a generator (4) for generating, based on the periodically changing signal (PS), a control signal (CS) for controlling the current source (7); wherein
 - the generator (4) is configured to update the control signal (CS) according to a pulse signal (clk) having a second frequency that is greater than the first frequency;
 - the generator (4) is configured to provide the pulse signal (clk) to the modulator (3); and
 - the modulator (3) is configured to update, based on the pulse signal (clk), the amplitude of the signal (PS) so that the amplitude of the signal (PS) periodically changes in steps, with the first frequency, around the amplitude of the output (C_{out}) of the controller (2).

2. The control IC (1) according to claim 1, wherein

- the modulator (3) is configured to generate the periodically changing signal (PS) such that the amplitude of the signal (PS) periodically changes in steps, with the first frequency, the periodically changing signal (PS) following a triangular waveform around the amplitude of the output (C_{out}) of the controller (2).

3. The control IC (1) according to any one of the previous claims, wherein

- the second frequency depends on the operating point of an operation of the current source (7).

4. The control IC (1) according to any one of the previous claims, wherein

- the modulator (3) is configured to update, every period of the pulse signal (clk), the amplitude of the signal (PS).

5. The control IC (1) according to any one of the previous claims, wherein the modulator (3) is configured to

- scale down the pulse signal (clk) received from the generator (4) using a scale n , n being a positive integer greater than or equal to two, and
- update, every n -th period of the pulse signal (clk), the amplitude of the signal (PS).

6. The control IC (1) according to claim 5, wherein
- the scale n depends on the second frequency of the pulse signal (clk).
- 5 7. The control IC (1) according to claim 5 or 6, wherein
- the control IC (1) is configured to obtain the scale n from a look-up table.
- 10 8. The control IC (1) according to any one of claims 5 to 7, wherein
- the control IC (1) is configured to obtain the scale n from outside the control IC (1), optionally from a micro-controller (5).
- 15 9. An operating device (13) for lighting means, optional at least one light emitting diode, LED; wherein the operating device (13) comprises
- a current source (7) configured to provide a current (I_{LM}) to the lighting means (8), and
 - a control IC (1) according to any one of the previous claims; wherein
 - the control IC (1) is configured to control the current source (7).
- 20 10. The operating device (13) according to claim 9, wherein
- the current source (7) comprises or is an actively switched DC/DC converter comprising at least one switch controllable for controlling the current (I_{LM}) providable by the current source (7) to the lighting means (8), and
 - the second frequency depends on the operating point of an operation of the actively switched DC/DC converter.
- 25 11. The operating device (13) according to claim 10, wherein
- the greater a switching frequency of the at least one switch of the actively switched DC/DC converter the greater the second frequency and vice versa.
- 30 12. The operating device (13) according to any one of claim 9 to 11, wherein
- the current source (7) comprises or is an actively switched DC/DC converter comprising at least one switch controllable for controlling the current (I_{LM}) providable by the current source to the lighting means (8),
 - the control IC (1) is a control IC (1) according to any one of claims 5 to 8, and
 - the scale n depends on the operating point of an operation of the actively switched DC/DC converter.
- 35 13. The operating device (13) according to claim 12, wherein
- the greater a switching frequency for switching the at least one switch of the actively switched DC/DC converter the greater the scale n and vice versa.
- 40 14. A luminaire (14) comprising,
- an operating device (13) according to any one of claims 9 to 13, and
 - lighting means (8), optional at least one light emitting diode, LED; wherein
 - the operating device (13) is configured to operate the lighting means (8).
- 45 15. A method for controlling, by a control integrated circuit (1), control IC, a current source (7) configured to provide a current to lighting means (8), optional at least one light emitting diode, LED; wherein
- the control IC (1) comprises
- a controller (2) for controlling the current (I_{LM}),
 - a modulator (3) for generating, based on an output (C_{out}) of the controller (2), a periodically changing signal (PS), wherein an amplitude of the signal (PS) periodically changes with a first frequency around an amplitude of the output (C_{out}) of the controller (2), and
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EP 4 231 783 A1

- a generator (4) for generating, based on the periodically changing signal (PS), a control signal (CS) for controlling the current source (7); and

- the method comprises

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- updating, by the generator (4), the control signal (CS) according to a pulse signal (clk) having a second frequency that is greater than the first frequency,
 - providing, by the generator (4), the pulse signal (clk) to the modulator (2), and
 - updating, by the modulator (2), based on the pulse signal (clk) the amplitude of the signal (PS) so that the
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- amplitude of the signal (PS) periodically changes in steps, with the first frequency, around the amplitude of the output (C_{out}) of the controller (2).

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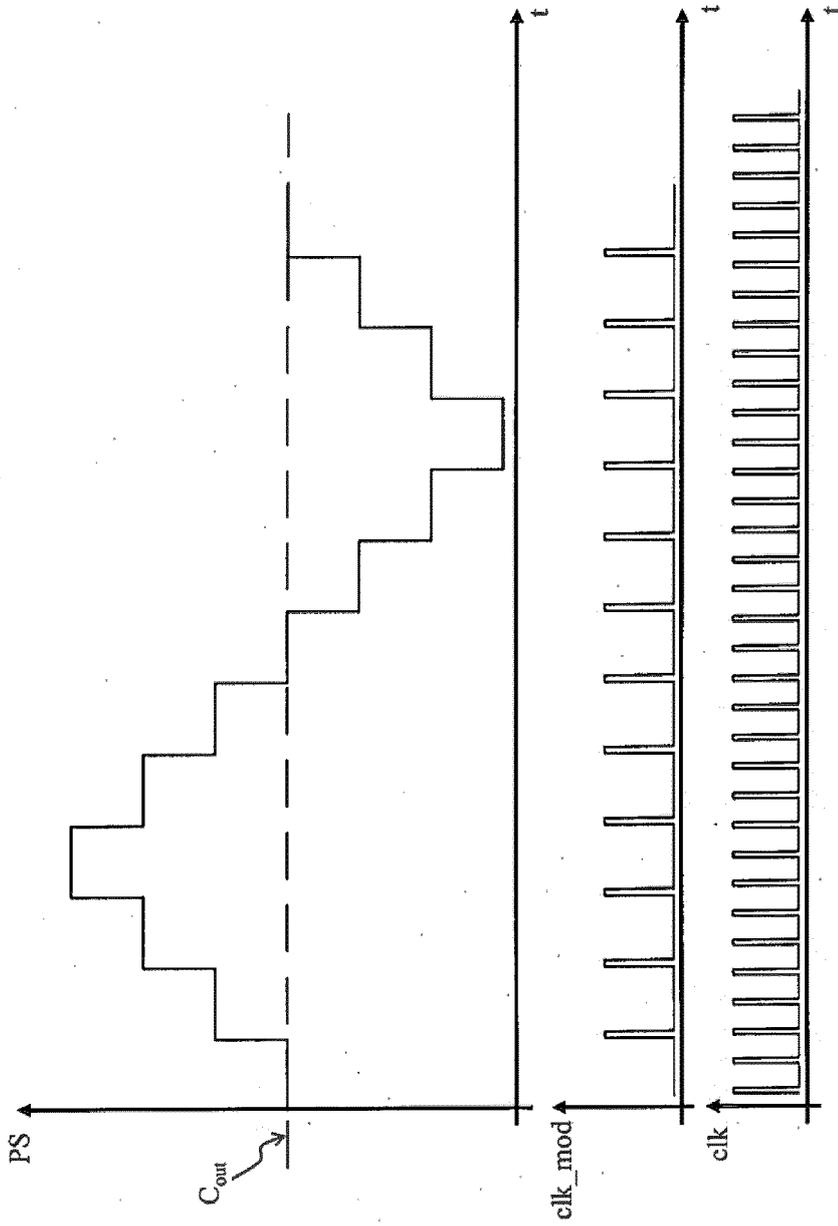


Figure 2

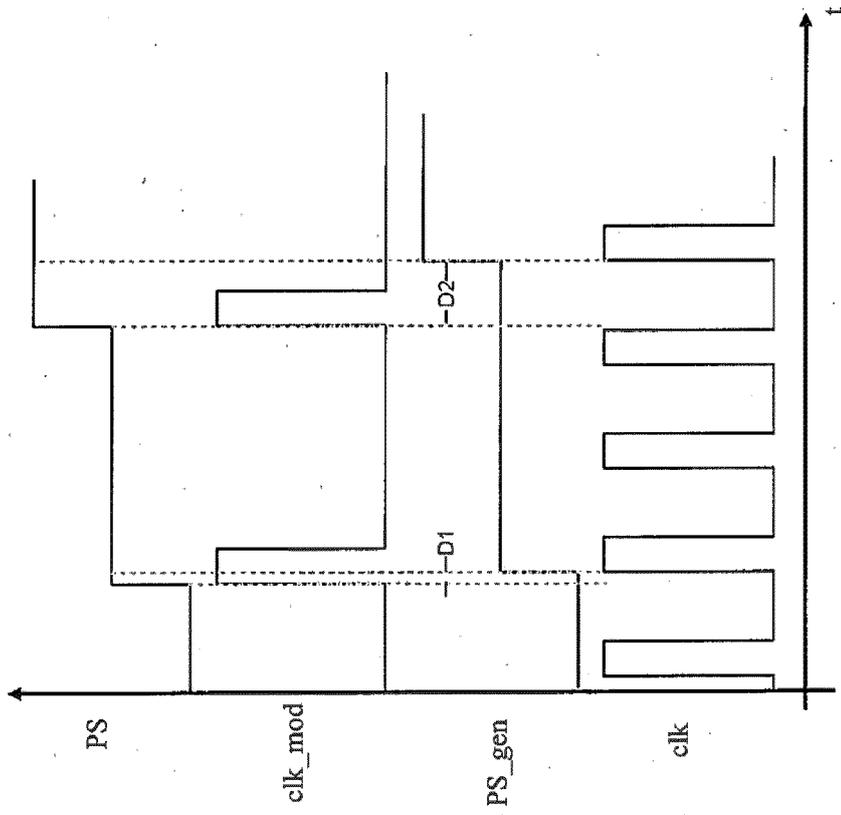


Figure 3

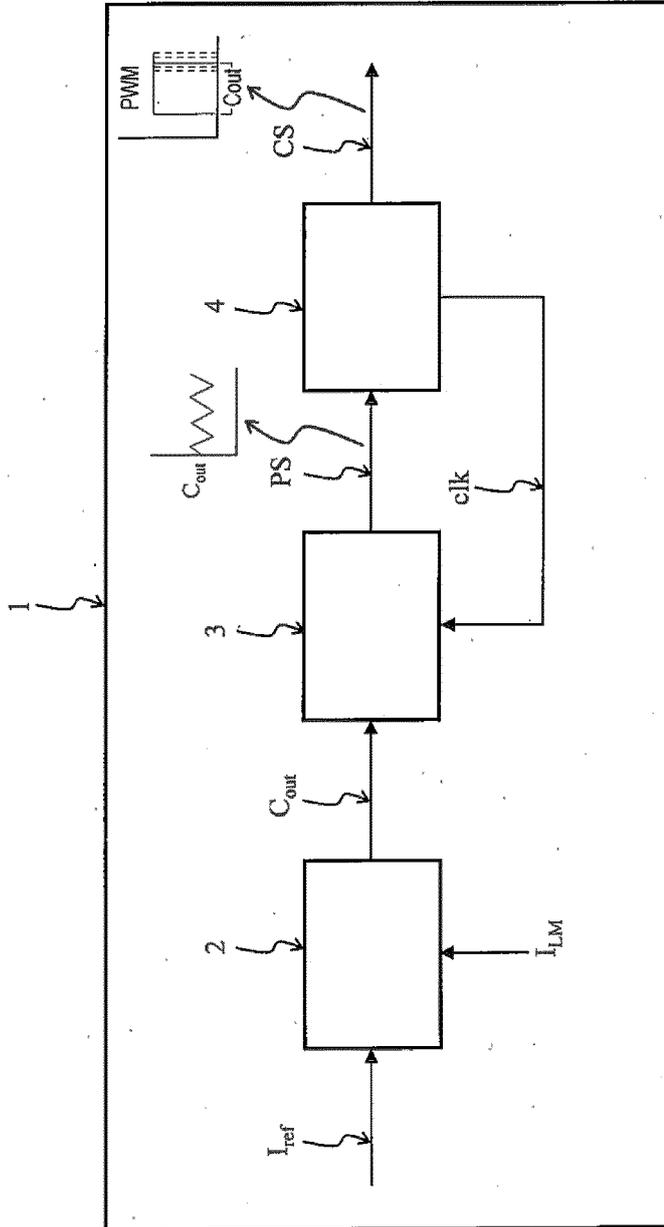


Figure 4

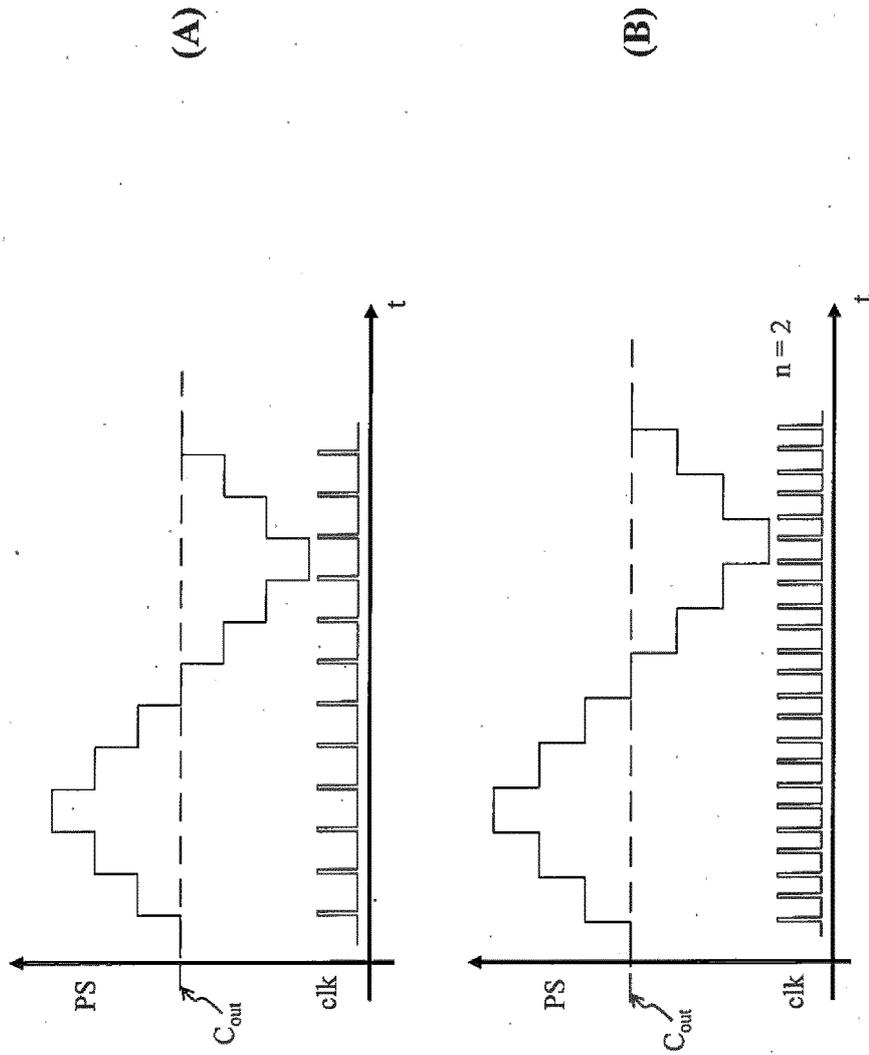


Figure 5

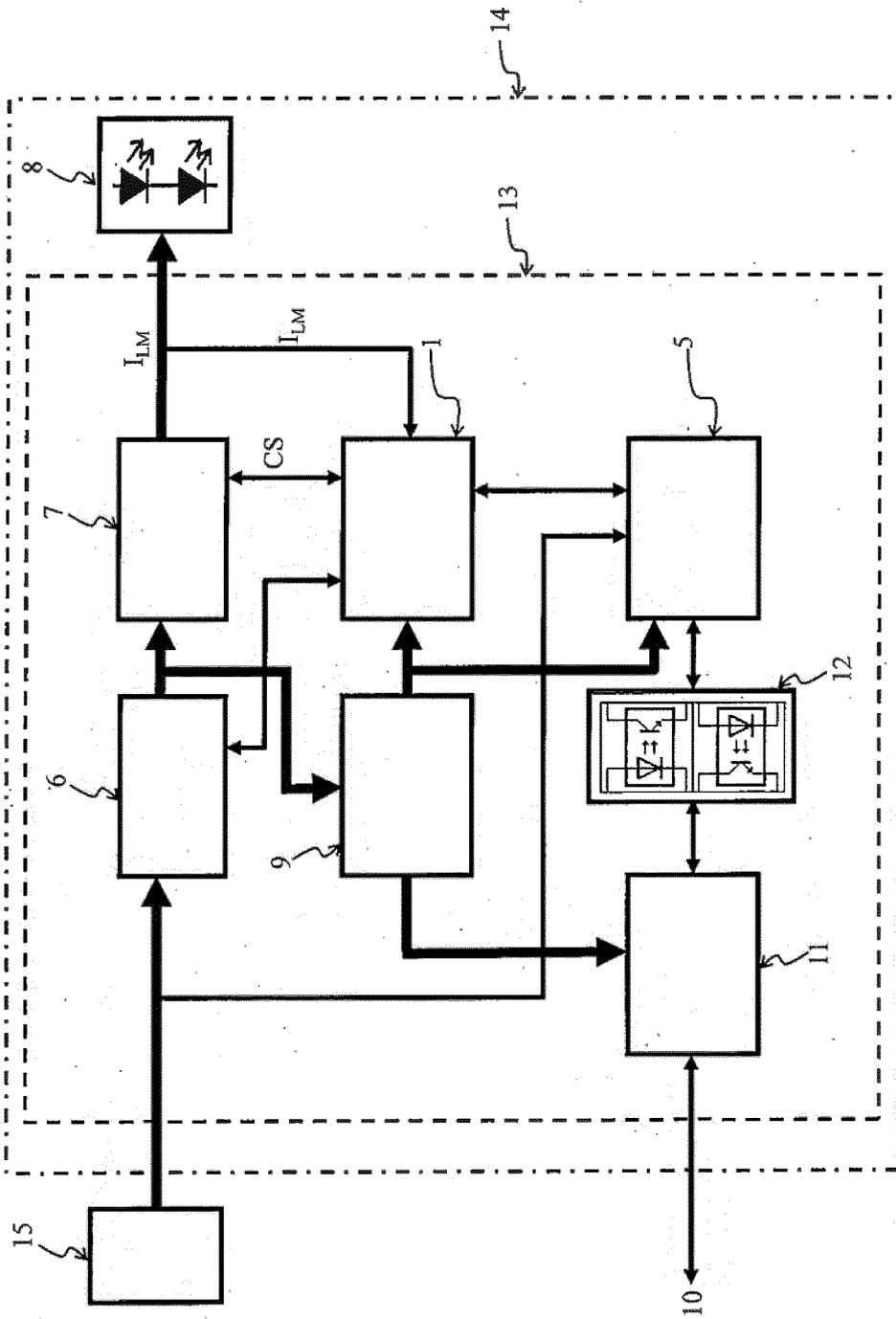


Figure 6



EUROPEAN SEARCH REPORT

Application Number

EP 22 15 7195

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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A	Linear Technology: "LT3761 Datasheet - 60VIN LED Controller with Internal PWM Generator", /, 17 August 2012 (2012-08-17), pages 1-28, XP055942340, Retrieved from the Internet: URL:https://web.archive.org/web/20130512083951if_/http://cds.linear.com:80/docs/en/datasheet/3761f.pdf [retrieved on 2022-07-13] * pages 10,15,28 *	1-15	
A	US 2015/194097 A1 (MARIANO GIANLUCA [IT] ET AL) 9 July 2015 (2015-07-09) * paragraphs [0030], [0034] - [0044]; figures 4-6 *	1-15	TECHNICAL FIELDS SEARCHED (IPC) H05B

The present search report has been drawn up for all claims

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Place of search Munich	Date of completion of the search 14 July 2022	Examiner Erskine, Andrew
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