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(54) **CONTROL SYSTEM AND METHOD FOR CONTROLLING AN ELECTRICAL SUPPLY CIRCUIT FOR LIGHTING MEANS, OPERATING DEVICE, LUMINAIRE AND LIGHTING SYSTEM**

(57) The invention relates to a control system (1) for controlling an electrical supply circuit (7) for electrically supplying lighting means (10), optional at least one light emitting diode, LED. The control system (1) comprises a control IC (1a) comprising an analog-to-digital-converter (2), ADC, for converting a measurement of at least one electrical quantity (EQ) of the electrical supply circuit (7) into a digital signal (DS). Further, the control system (1) comprises signal processing means (3) for processing

the digital signal (DS), and the control IC (1a) comprises a controller (4) for controlling the at least one electrical quantity (EQ). The signal processing means (3) is configured to perform a statistical evaluation of the digital signal (DS). The controller (4) is configured to control, based on the digital signal (DS), the at least one electrical quantity (EQ) using the statistical evaluation of the digital signal (DS).

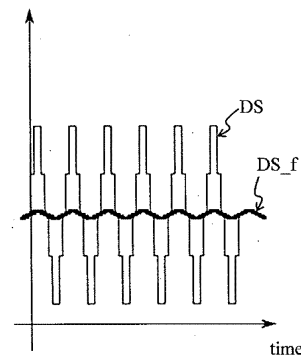
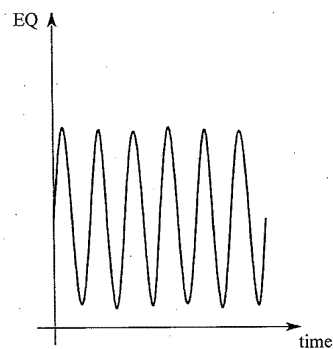


Figure 2

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Description

[0001] The invention relates to a control system for controlling an electrical supply circuit for electrically supplying lighting means, an operating device for lighting means, the operating device comprising such a control IC, and a luminaire comprising such an operating device. The invention further relates to a lighting system and a method for controlling an electrical supply circuit for electrically supplying lighting means.

[0002] A control integrated circuit (control IC), such as an application specific integrated circuit (ASIC) or field programmable gate array (FPGA), may be used for controlling an electrical supply circuit for electrically supplying lighting means, such as one or more light emitting diodes (LEDs). For controlling the electrical supply circuit and, thus, the electrical supply of the lighting means the control IC may control at least one electrical quantity of the electrical supply circuit. The electrical quantity may be a current, a voltage or an electrical energy of the electrical supply circuit that is used for electrically supplying the lighting means. For example, the electrical quantity may be an output current providable by the electrical supply circuit to the lighting means or a supply voltage generated by the electrical supply circuit, from which supply voltage the lighting means are electrically supplied.

[0003] **Figure 1** shows a block diagram of an example of a control IC for controlling an electrical supply circuit for electrically supplying lighting means. As shown in **Figure 1**, the control IC 1a may comprise an analog-to-digital converter 2 (ADC) for converting a measurement of at least one electrical quantity EQ of the electrical supply circuit into a digital signal DS, wherein the electrical quantity may have a ripple (such as a DC voltage with a ripple). Further, the control IC 1a may comprise signal processing means 3 for processing the digital signal DS. The signal processing means 3 may filter the digital signal DS using a moving average filter 3a and provide the filtered digital signal DS_f to a controller 4 of the control IC 1a. Thus, the values of the filtered digital signal DS_f represent the means value of the values of the digital signal DS so that the ripple of the filtered digital signal DS_f has a smaller amplitude compared to the ripple of the digital signal DS. With other words, the filtered digital signal DS_f has a smaller ripple compared to the digital signal DS. The controller 4 is configured to control, based on the filtered digital signal DS_f, the at least one electrical quantity by generating a control output ctrl_out. Based on the ctrl_out the control IC 1a may control the electrical supply circuit, thereby controlling the at least one electrical quantity EQ of the electrical supply circuit and, thus, a light emission of the lighting means. For example, the control IC 1a, optionally a driver module or driver logic of the control IC 1a, may generate based on the control output ctrl_out of the controller 4 a control signal for controlling the electrical supply circuit.

[0004] **Figure 2** shows an example of waveforms of a ripple of an electrical quantity of an electrical supply circuit

and a digital signal of the ripple over time. In particular, the graph on the left side of **Figure 2** shows an example of a waveform of the ripple of the at least one electrical quantity EQ of the electrical supply circuit, which may be controlled by the control IC 1a of **Figure 1**. The at least one electrical quantity EQ may for example be a direct current (DC current) or direct voltage (DC voltage) having a ripple. The ripple is visible in the left graph of **Figure 2**

[0005] The graph on the right side of **Figure 2** exemplarily shows a waveform of the digital signal DS (thin line) that may be generated by the ADC 2 of the control IC 1a of **Figure 1**. In addition, the graph on the right side of **Figure 2** exemplarily shows a waveform of the filtered digital signal DS_f (bold line) corresponding to the digital signal DS processed by the signal processing means 3 of the control IC 1a of **Figure 1**. As shown in **Figure 2**, the ripple of the filtered digital signal DS_f has a smaller amplitude compared to the ripple of the digital signal DS.

[0006] **Figure 3** shows an example of waveforms of a ripple of an electrical quantity of an electrical supply circuit and a digital signal of the ripple over time.

[0007] In particular, the left and right graphs of **Figure 3** correspond to the left and right graphs of **Figure 2**, respectively, wherein in the example of **Figure 3** there are disturbances of the at least one electrical quantity EQ present. These disturbances are illustrated in the left graph of **Figure 3** by higher or greater amplitudes of the ripple of the signal (analog signal, e.g. voltage) representing the at least one electrical quantity EQ with regard to the rest of the signal. That is, the disturbances are visible in the left graph in the form of a higher ripple of the signal representing the at least one electrical quantity EQ with regard to the rest of the signal. These disturbances are also visible in the digital signal DS (thin line) output by the ADC 2 of the control IC 1a and the filtered digital signal DS_f (bold line) output by the signal processing means 3 of the control IC 1a, as shown in the right graph of **Figure 3**. These disturbances are illustrated in the right graph of **Figure 3** by higher amplitudes of the ripple of the digital signal DS and the filtered signal DS_f compared to the rest of the respective signal. Therefore, when disturbances of the at least one electrical quantity EQ occur, then these disturbances are input to the controller 4 of the control IC 1a (namely the disturbances are visible in the filtered digital signal DS_f). Such variations (disturbances) in the input of the controller 4 of the control IC 1a may lead to an unstable control by the controller 4, which may be visible in the light emission of the lighting means, e.g. in the form of light flickering. In particular, the control, e.g. feedback control, performed by the controller 4 of the control IC 1a of the at least one electrical quantity EQ based on the filtered digital signal DS_f may be fast enough to react to the variation of the amplitude of the ripple of the filtered digital signal DS_f. This variation is caused by the disturbances of the at least one electrical quantity EQ and, thus, the controller 4 should not react or consider this increase of the ripple of the

filtered digital signal DS_f. However, since the controller 4 is fast enough to react to the aforementioned variation of the amplitude of the filtered digital signal's DS_f ripple, the light emission of the lighting means, which depends on the control of the electrical supply circuit by the control IC, is influenced by the aforementioned ripple variation. Thus, the disturbances of the at least one electrical quantity EQ are visible in the light emission for a person, e.g. in the form of a light intensity or luminance variation. For example, a light flickering may occur that is visible for the human eye.

[0008] In view of the above, it is an object of the invention to provide an improved control system, the control system comprising a control IC, for controlling an electrical supply circuit for electrically supplying lighting means. It is in particular an object of the invention to provide a control system, the control system comprising a control IC, for controlling an electrical supply circuit for electrically supplying lighting means, which may control the electrical supply circuit and, thus, light emission of the lighting means without the above described disadvantage.

[0009] 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.

[0010] According to a first aspect of the invention, a control system for controlling an electrical supply circuit for electrically supplying lighting means is provided. The lighting means are optionally at least one light emitting diode (LED). The control system comprises a control integrated circuit (control IC). The control IC comprises an analog-to-digital-converter (ADC) for converting a measurement of at least one electrical quantity of the electrical supply circuit into a digital signal. Further, the control system comprises signal processing means for processing the digital signal, and the control IC comprises a controller for controlling the at least one electrical quantity. The signal processing means is configured to perform a statistical evaluation of the digital signal. The controller is configured to control, based on the digital signal, the at least one electrical quantity using the statistical evaluation of the digital signal.

[0011] In other words, the first aspect of the invention proposes to perform a statistical evaluation of the at least one measured electrical quantity that is input to the ADC of the control IC and to provide the statistical evaluation (i.e. a result of the statistical evaluation) to the controller of the control IC. This allows the controller of the control IC to consider the statistical evaluation when controlling the at least one electrical quantity based on the digital signal. As a result the controller may be configured to determine or detect based on the digital signal a case, when disturbances of the at least one electrical quantity is present causing a greater ripple of the digital signal, and consider such a case for controlling the at least one electrical quantity. Therefore, the control system, in par-

ticular the control IC or the controller of the control IC, may be configured to prevent that disturbances of the at least one electrical quantity have an impact on the control of the at least one electrical quantity preventing that the disturbances are visible in a control output of the controller and a light emission of the lighting means. Thus, the control system of the first aspect comprising the control IC is advantageous with regard to the control IC of Figure 1.

[0012] The control system, in particular the control system's control IC, may be configured to control the electrical supply circuit according to the control of the at least one electrical quantity of the electrical supply circuit that is performable by the controller of the control IC. The control IC may be configured to control the electrical supply circuit by generating a control signal (e.g. a PWM signal) based on an output or control result of the controller. That is, the control IC may be configured to control the electrical supply circuit by generating the control signal based on an output or control results of a control (e.g. feedback control and/or feedforward control) of the at least one electrical quantity by the controller.

[0013] The at least one electrical quantity (i.e. the one or more electrical quantities) of the electrical supply circuit may be one or more electrical quantities for electrically supplying the lighting means. For example, the at least one electrical quantity may be a voltage of the electrical supply circuit, from which (e.g. a bus voltage of a supply bus or intermediate voltage of the electrical supply circuit) or with which (e.g. an output voltage of the electrical supply circuit) the lighting means are electrically supplyable. In addition or alternatively, the at least one electrical quantity may be a current of the electrical supply circuit, from which (e.g. a bus current of a supply bus or an intermediate current of the electrical supply circuit) or with which (e.g. an output current of the electrical supply circuit) the lighting means are electrically supplyable.

[0014] The at least one electrical quantity may be a direct quantity, for example a direct voltage (DC voltage) and/or a direct current (DC current), having a ripple. In the left graph of Figures 2 and 3, an example of a ripple of an electrical quantity, such as a DC current or DC voltage, is shown.

[0015] Optionally, the control system, in particular the control system's control IC, is configured to control the electrical supply of the lighting means from the electrical supply circuit by controlling the at least one electrical quantity so that increasing the at least one electrical quantity increases an amount, intensity or illuminance of the light emission of the lighting means and vice versa. The control system, in particular the control IC, may be configured to control the at least one electrical quantity so that increasing a time average of the at least one electrical quantity (e.g. a current, voltage and/or electrical power) increases the amount, intensity or illuminance of the light emission and vice versa. The time average of a quantity may be understood as the average of the quantity over time, e.g. a certain time period. The term "elec-

trical parameter" or "electrical variable" may be used as a synonym for the term "electrical quantity".

[0016] The measurement of the at least one electrical quantity may be a measurement signal (in short signal) or a voltage that represents or indicates the at least one measured electrical quantity. For example, in case the at least one electrical quantity is a current of the electrical supply circuit, then the measurement of the current may be performed using a shunt resistor so that the voltage generated at the shunt resistor when the current flows through the resistor represent or indicates the current (e.g. the magnitude or value of the current).

[0017] The ADC may be configured to convert the measurement of the at least one electrical quantity of the electrical supply circuit into a digital signal (of the electrical quantity). The ADC may be configured to convert an analog signal (measurement signal) of the at least one electrical quantity into a digital signal (of the electrical quantity). The measurement of the at least one electrical quantity may be a measurement signal that is an analog signal.

[0018] The controller may be configured to control the at least one electrical quantity by performing a feedback control and/or a feedforward control of the at least one electrical quantity. The terms "closed-loop control" may be used as a synonym for the term "feedback control" and the term "open-loop control" may be used as synonym for the term "feedforward control". The controller may be configured to perform a feedback control of the at least one electrical quantity with regard to a reference variable or value for the at least one electrical quantity. The controller may be configured to perform a feedforward control of an electrical quantity of the electrical supply circuit using another electrical quantity of the electrical supply circuit.

[0019] The electrical supply circuit may be part of an operating device for lighting means or may be an operating device for lighting means. In case the lighting means are at least one LED, such an operating device may be referred to as LED-driver. The operating device may be a ballast for lighting means.

[0020] The control IC may be an application specific integrated circuit (ASIC), a microcontroller or a field programmable gate array (FPGA).

[0021] For example, the controller may be or may comprise a P controller, a PI controller and/or a PID controller. The controller may be or may comprise any other controller type, for example a state controller.

[0022] The ADC may be configured to provide the digital signal to the signal processing means. The signal processing means may be configured to provide the statistical evaluation of the digital signal to the controller.

[0023] The terms "statistical computation" or "statistical calculation" may be used as synonyms for the term "statistical evaluation".

[0024] According to an optional alternative, the control IC comprises the signal processing means. Thus, the statistical evaluation of the digital signal may be per-

formed in or by the control IC. In this case, the control system and the control IC may be optionally the same entity.

[0025] According to another optional alternative, the control system may comprise a microcontroller and the microcontroller may comprise the signal processing means. Thus, the statistical evaluation of the digital signal may be performed in or by a microcontroller of the control system. That is, the statistical evaluation may be performed outside the control IC.

[0026] In this case, the control IC, in particular the ADC, may be configured to provide or communicate the digital signal to the microcontroller, in particular to the signal processing means of the microcontroller. The microcontroller, in particular the signal processing means of the microcontroller, may be configured to provide or communicate the statistical evaluation of the digital signal to the control IC, in particular the controller.

[0027] Optionally, the signal processing means is configured to filter, using a moving average filter, the digital signal. Optionally, the signal processing means is configured to perform the statistical evaluation by statistically evaluating the filtered digital signal.

[0028] In other words, the signal processing means may be configured to compute a moving average of the digital signal, e.g. values or data points of the digital signal. Optionally, the signal processing means may be configured to perform the statistical evaluation by statistically evaluating the computed moving average of the digital signal, e.g. the computed moving average of the values or data points of the digital signal.

[0029] The terms "rolling average" and "running average" may be used for the term "moving average".

[0030] Optionally, when the microcontroller comprises the signal processing means for performing the statistical evaluation of the digital signal, the control IC may comprise a second signal processing means configured to filter, using a moving average filter, the digital signal. The second signal processing means may be configured to provide the filtered digital signal to the controller. Optionally, the second signal processing means may be configured to provide the filtered digital signal to the signal processing means of the microcontroller and the signal processing means may be configured to perform the statistical evaluation by statistically evaluating the filtered digital signal received from the second signal processing means.

[0031] The controller may be configured to control, based on the digital signal, the at least one electrical quantity using the filtered digital signal received from the second signal processing means and the statistical evaluation of the digital signal received from the signal processing means of the microcontroller.

[0032] The controller may be configured to control, based on the digital signal, the at least one electrical quantity using the filtered digital signal and the statistical evaluation of the digital signal. The signal processing means may be configured to provide the filtered digital

signal to the controller.

[0033] The filtered digital signal, being generated using the moving average filter, has a smaller ripple (ripple amplitude) compared to the digital signal. In other words, the values or data points of the filtered digital represent the mean value of values or data points of the digital signal with a smaller ripple compared to the values or data points of the digital signal. This increases stability of the control of the at least one electrical quantity by the controller, to which the filtered digital signal is provided or input. Increasing stability of the control of the at least one electrical quantity increases stability of the light emission of the lighting means.

[0034] The signal processing means may be configured to provide or input the filtered digital signal to the controller so that the controller uses the filtered digital signal and the statistical evaluation of the digital signal for controlling the at least one electrical quantity.

[0035] The signal processing means may be configured to perform the statistical evaluation by computing a standard deviation of the digital signal. Optionally, the signal processing means is configured to perform the statistical evaluation by computing a standard deviation of the filtered digital signal.

[0036] In other words, the signal processing means may be configured to compute the standard deviation of the values or data points of the digital signal or the filtered digital signal (e.g. of a certain time period).

[0037] Optionally, the signal processing means may be configured to compute one or more additional statistical values, such as mean value, minimum value, maximum value, etc., of the digital signal or the filtered digital signal. That is, the signal processing means may be configured to compute one or more additional statistical values, such as mean value, minimum value, maximum value, etc., of the values or data points of the digital signal or the filtered digital signal (e.g. of a certain time period).

[0038] Optionally, the controller is configured to determine whether the standard deviation is greater than a threshold for the standard deviation, and keep its output constant at a last value, during a time period when the standard deviation of the digital signal (optional of the filtered digital signal) is greater than the threshold for the standard deviation. The last value is a value lastly output by the controller before determining that the standard deviation is greater than the threshold for the standard deviation.

[0039] The controller may be configured to determine that disturbances of the at least one electrical quantity (e.g. in the form of an increase of a ripple of the at least one electrical quantity) and, thus, disturbances in the digital signal are present, when the controller determines that the standard deviation of the digital signal is greater than the threshold for the standard deviation. By keeping its output constant at the last value, during the time period when the standard deviation is greater than the threshold, the controller is configured to prevent that the disturbances of the electrical quantity have an impact on the control

of the at least one electrical quantity and, thus, on the light emission of the lighting means.

[0040] In other words, the standard deviation of the digital signal may be an indicator for whether disturbances are present or not. By setting the threshold for the standard deviation, the degree of disturbances (e.g. the magnitude or amplitude of the ripple of the electrical quantity) that may be tolerated may be set. The lower or smaller the threshold for the standard deviation the lower or smaller the degree of disturbances that is tolerated and vice versa. In other words, changing the threshold for the standard deviation allows changing the sensitivity of detecting the disturbances. The greater the threshold, the lower the sensitivity and vice versa.

[0041] The signal processing means may be configured to perform the statistical evaluation by additionally computing a mean value of the digital signal. Optionally, the signal processing means is configured to perform the statistical evaluation by additionally computing a mean value of the filtered digital signal. The controller may be configured to determine whether the standard deviation is greater than a threshold for the standard deviation. Further, the controller may be configured to ignore the digital signal and use a last mean value of the digital signal for controlling the at least one electrical quantity, during a time period when the standard deviation of the digital signal (optional of the filtered digital signal) is greater than the threshold for the standard deviation. Optionally, the controller may be configured to ignore the filtered digital signal and use a last mean value of the filtered digital signal for controlling the at least one electrical quantity, during a time period when the standard deviation of the digital signal (optional of the filtered digital signal) is greater than the threshold for the standard deviation. The last mean value is a mean value lastly computed before determining that the standard deviation is greater than the threshold for the standard deviation.

[0042] In other words, the signal processing means may be configured to compute the mean value of the values or data points of the digital signal or the filtered digital signal (e.g. of a certain time period).

[0043] Optionally, the controller is configured to determine whether the standard deviation is greater than a threshold for the standard deviation. The controller may be configured to ignore the filtered digital signal and use a last value of the filtered digital signal for controlling the at least one electrical quantity, during a time period when the standard deviation of the digital signal (optional of the filtered digital signal) is greater than the threshold for the standard deviation. The last value of the filtered digital signal is a value of the filtered digital signal lastly received before determining that the standard deviation is greater than the threshold for the standard deviation.

[0044] The control IC may be configured to receive the threshold for the standard deviation from outside (e.g. from a user). Optionally, the control IC is configured to receive the threshold for the standard deviation from a microcontroller of the control system.

[0045] The signal processing means may comprise a statistics module configured to perform the statistical evaluation. The statistics module may be configured to be turned on and off from outside. Optionally, the statistics module is configured to be turned on and off by a user. That is, the signal processing means, in particular the statistics module, may be configured to receive a control signal or instruction from outside, optionally triggered by a user, instructing the statistics module to turn on or off. The statistics module may be configured to turn on respectively off in response to such a control signal or instruction. In other words, the statistics module may be triggered from outside, optionally by a user, to be turned on and off.

[0046] The statistics module may be configured to be controlled from outside, optionally from a user, such that the statistical evaluation is reset. That is, the signal processing means, in particular the statistics module, may be configured to receive a control signal or instruction from outside, optionally triggered by a user, instructing the statistics module to reset the statistical evaluation. The statistics module may be configured to reset the statistical evaluation in response to such a control signal or instruction. In other words, the statistics module may be configured to be triggered from outside, optionally by a user, to reset the statistical evaluation (e.g. after a load jump).

[0047] Optionally, the signal processing means may be configured to receive information (e.g. a parameter) on a filter length of the moving average filter from outside, optionally from a user. In other words, the signal processing means may be configured to receive information (e.g. a parameter) on a number of samples of the digital signal that are to be used (or should be considered) for filtering, using the moving average filter, the digital signal.

[0048] The control IC may comprise the signal processing means and the statistics module of the signal processing means may be configured to be turned on and off from a microcontroller of the control system. In other words, the statistics module may be triggered by a microcontroller of the control system to be turned on and off. Optionally, the statistics module may be configured to be triggered by a microcontroller of the control system to reset the statistical evaluation (e.g. after a load jump). Optionally, the signal processing means may be configured to receive information (e.g. a parameter) on a filter length of the moving average filter from a microcontroller of the control system.

[0049] The control system may be configured to provide the statistical evaluation to outside. Optionally, the control system is configured to provide the statistical evaluation to a user. For this, the control system may be configured to be connected to a display on which the statistical evaluation may be displayed. The control system may be configured to receive information on performing the statistical evaluation from outside, optional from a user. Optionally, the control system is configured to receive information on a number of samples of the

digital signal to be used for the statistical evaluation from outside, optional from a user. That is, the control IC may be configured to receive information on a number of samples of the digital signal that should be considered for the statistical evaluation from outside, optional from a user.

[0050] The control IC may comprise the signal processing means and the control IC may be configured to provide the statistical evaluation to a microcontroller of the control system 1. The control IC is configured to receive information on performing the statistical evaluation from a microcontroller of the control system. Optionally, the control IC is configured to receive information on the number of samples of the digital signal to be used for the statistical evaluation from a microcontroller of the control system.

[0051] The terms "values of the digital signal", "data points of the digital signal" and "samples of the digital signals" may be used as synonyms.

[0052] Optionally, the at least one electrical quantity is at least one of the following: an output voltage of an AC/DC converter (e.g. the AC/DC converter is a power factor correction (PFC) circuit), an output current of an AC/DC converter (e.g. a PFC circuit), an output voltage of a DC/DC converter, and an output current of a DC/DC converter.

[0053] The DC/DC converter may be an actively switched DC/DC converter with at least one switch. Examples of an actively switched DC/DC converter comprise a buck-converter, boost-converter, buck-boost-converter, flyback converter, resonance converter etc. A conversion of a first DC power, DC voltage or DC current to a second DC power, DC voltage respectively DC current by the actively switched DC/DC converter is controllable by controlling switching of the at least one switch of the actively switched DC/DC converter. The second DC quantity (i.e. power, voltage or current) may be greater or smaller than the first DC quantity depending on the type of 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. Thus, the control IC may be configured to control conversion of a first DC power, DC voltage or DC current to a second DC power, DC voltage; respectively DC current by controlling switching of the at least one switch of the actively switched DC/DC converter.

[0054] The AC/DC converter may be an actively switched AC/DC converter with at least one switch. A conversion of an AC power, AC voltage or AC current to a DC power, DC voltage respectively DC current by the actively switched AC/DC converter is controllable by controlling switching of the at least one switch. The control IC may be configured to control switching of the at least one switch of the actively switched AC/DC converter. Thus, the control IC may control conversion of an AC power, AC voltage or AC current to a DC power, DC voltage respectively DC current by controlling switching of the at least one switch of the actively switched AC/DC converter. The AC/DC converter may be an actively

switched PFC circuit with at least one switch. The power factor correction function is controllable by controlling switching of the at least one switch of the actively switched PFC circuit. The control IC may be configured to control switching of the at least one switch of the actively switched PFC circuit. Thus, the control IC may be configured to control the PFC function of the PFC circuit by controlling switching of the at least one switch of the PFC circuit.

[0055] For example, the AC/DC converter may comprise a rectifier circuit and an actively switched DC/DC converter with at least one switch. The control IC may be configured to control switching of the at least one switch of the actively switched DC/DC converter.

[0056] In order to achieve the control system according to the first aspect of the invention, some or all of the above described optional features may be combined with each other.

[0057] 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 control system according to the first aspect, as described above, and an electrical supply circuit for electrically supplying the lighting means. Optionally, the electrical supply circuit is or comprises an AC/DC converter, e.g. PFC circuit (power factor correction circuit), and/or a DC/DC converter. The control system is configured to control the electrical supply circuit.

[0058] The AC/DC converter may be an actively switched AC/DC converter with at least one switch. The AC/DC converter may be a PFC circuit. In other words, the AC/DC converter may be configured to provide a PFC function. The PFC circuit may be an actively switched PFC circuit with at least one switch. The DC/DC converter may be an actively switched DC/DC converter with at least one switch. The DC/DC converter may be a current source or voltage source. An output of the AC/DC converter (e.g. PFC circuit) may be electrically connected to an input of the DC/DC converter. In other words, the AC/DC converter may be configured to electrically supply the DC/DC converter from an AC electrical energy source, such as mains.

[0059] The control IC of the control system may be configured to control switching of the at least one switch of the actively switched DC/DC converter according to a control of the respective electrical quantity providable by the actively switched DC/DC converter (e.g. according to an output current or output voltage of the actively switched DC/DC converter). The control IC of the control system may be configured to control switching of the at least one switch of the actively switched AC/DC converter according to a control of the respective electrical quantity providable by the actively switched AC/DC converter (e.g. according to an output current or output voltage of the actively switched AC/DC converter).

[0060] In case the lighting means are at least one LED, the operating device may be referred to as LED-driver.

The operating device may be a ballast for lighting means.

[0061] Optionally, the control system comprises a microcontroller. The microcontroller may be configured to provide the threshold for the standard deviation to the control IC of the control system. Optionally, the control IC may comprise the signal processing means of the control system and the microcontroller of the control system may be configured to provide information on performing the statistical evaluation to the control IC. Optionally, the microcontroller is configured to provide information on a number of samples of the digital signal to be used for the statistical evaluation to the control IC.

[0062] The above description with regard to the control system 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 of the AC/DC converter and the DC/DC converter with regard to the control system according to the first aspect is also valid for the electrical supply circuit of the operating device according to the second aspect. The above description of the operating device according to the second aspect of the invention is also valid for the control system according to the first aspect of the invention.

[0063] The operating device according to the second aspect of the invention achieves the same advantages as the control system according to the first aspect of the invention.

[0064] 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.

[0065] According to a third aspect of the invention, a luminaire is provided. The luminaire comprises the operating device according to the second aspect, as described above, and lighting means. The lighting means are optionally at least one light emitting diode (LED). The operating device is configured to operate the lighting means.

[0066] 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.

[0067] The luminaire according to the third aspect of the invention achieves the same advantages as the control system according to the first aspect of the invention.

[0068] According to a fourth aspect of the invention, a lighting system is provided. The lighting system comprises an operating device for lighting means. Optionally, the lighting means are at least one light emitting diode (LED). Further, the lighting system comprises a central unit configured to communicate with the operating device. The operating device comprises an electrical supply circuit for electrically supplying the lighting means. The electrical supply circuit may comprise or be an AC/DC converter (e.g. a PFC circuit) and/or a DC/DC converter. The operating device further comprises a control IC for controlling the electrical supply circuit. The control IC comprises an analog-to-digital-converter (ADC) for converting a

measurement of at least one electrical quantity of the electrical supply circuit into a digital signal, and a controller for controlling the at least one electrical quantity. The central unit comprises signal processing means for processing the digital signal. The signal processing means is configured to perform a statistical evaluation of the digital signal. The controller is configured to control, based on the digital signal, the at least one electrical quantity using the statistical evaluation of the digital signal.

[0069] Optionally, the operating device of the lighting system is an operating device according to the second aspect of the invention. In other words, the operating device of the lighting system may optionally be implemented like the operating device according to the second aspect of the invention.

[0070] The above description of the control system according to the first aspect of the invention and the above description of the operating device according to the second aspect of the invention is correspondingly valid for the lighting system according to the fourth aspect of the invention. In particular, the above description of the control IC of the control system of the first aspect is correspondingly valid for the control IC of the operating device of the lighting system of the fourth aspect. For example, the description of the ADC and the controller of the control IC of the control system of the first aspect is also valid for the ADC and the controller of the control IC of the operating device of the lighting system of the fourth aspect. With regard thereto, the operating device of the lighting system may comprise a microcontroller. The microcontroller and the control IC of the operating device may form a control system. In particular, the above description of the signal processing means of the control system of the first aspect is correspondingly valid for the signal processing means of the central unit of the lighting system of the fourth aspect.

[0071] The above description of the AC/DC converter and the DC/DC converter with regard to the control system according to the first aspect and the above description of the electrical supply circuit of the operating device according to the second aspect is also valid for the electrical supply circuit of the operating device of the lighting system according to the fourth aspect.

[0072] The central unit and the operating device may be configured to communicate with each other. This communication may be wireless (e.g. via Bluetooth) and/or wire-bound (e.g. via a wired bus).

[0073] The operating device, in particular the control IC or the ADC of the control IC, may be configured to provide the digital signal to the central unit, in particular to the signal processing means of the central unit. The control IC, in particular the ADC, may be configured to provide the digital signal via the optional microcontroller of the operating device to the central unit. That is, the optional microcontroller of the operating device may be configured to communicate with outside the operating device, e.g. with the central unit of the lighting system.

This communication may be wireless (e.g. via Bluetooth) and/or wire bound. For example, the microcontroller may be configured to communicate via a wired bus, e.g. a DALI bus or DALI-2 bus, with the central unit of the lighting system. Thus, the control IC, in particular the ADC, may be configured to provide the digital signal to the microcontroller and the microcontroller may be configured to provide or communicate the digital signal receivable from the control IC to the central unit of the lighting system. The microcontroller may be configured to provide or communicate data or information from the operating device, such as data or information received from the control IC, to the central unit.

[0074] Correspondingly, the central unit, in particular the signal processing means, may be configured to provide the statistical evaluation of the digital signal to the operating device, in particular the control IC or the controller of the control IC. The central unit, in particular the signal processing means, may be configured to provide or communicate the statistical evaluation of the digital signal to the optional microcontroller of the operating device and the microcontroller may be configured to provide the received statistical evaluation of the digital signal to the control IC, in particular to the controller of the control IC. The central unit may be configured to provide or communicate data or information, such as data or information of the signal processing means (e.g. results of a statistical evaluation performed by the signal processing means), to the operating device, in particular to the optional microcontroller of the operating device. The microcontroller may provide received data or information (e.g. received from outside the operating device) to the control IC.

[0075] Optionally, the signal processing means of the central unit is configured to filter, using a moving average filter, the digital signal. Optionally, the signal processing means is configured to perform the statistical evaluation by statistically evaluating the filtered digital signal.

[0076] Optionally, the control IC of the operating device may comprise a second signal processing means configured to filter, using a moving average filter, the digital signal. The second signal processing means may be configured to provide the filtered digital signal to the controller. Optionally, the second signal processing means may be configured to provide the filtered digital signal to the signal processing means of the central unit and the signal processing means may be configured to perform the statistical evaluation by statistically evaluating the filtered digital signal received from the second signal processing means.

[0077] The controller of the control IC of the operating device may be configured to control, based on the digital signal, the at least one electrical quantity using the filtered digital signal received from the second signal processing means and the statistical evaluation of the digital signal received from the signal processing means of the central unit.

[0078] The controller of the control IC of the operating device may be configured to control, based on the digital

signal, the at least one electrical quantity using the filtered digital signal and the statistical evaluation of the digital signal. The signal processing means of the central unit may be configured to provide the filtered digital signal to the controller.

[0079] The signal processing means of the central unit may be configured to perform the statistical evaluation by computing a standard deviation of the digital signal. Optionally, the signal processing means is configured to perform the statistical evaluation by computing a standard deviation of the filtered digital signal.

[0080] Optionally, the signal processing means of the central unit may be configured compute one or more additional statistical values, such as mean value, minimum value, maximum value, etc., of the digital signal or the filtered digital signal. That is, the signal processing means of the central unit may be configured to compute one or more additional statistical values, such as mean value, minimum value, maximum value, etc., of the values or data points of the digital signal or the filtered digital signal (e.g. of a certain time period).

[0081] Optionally, the controller of the control IC of the operating device is configured to determine whether the standard deviation is greater than a threshold for the standard deviation, and keep its output constant at a last value, during a time period when the standard deviation of the digital signal (optional of the filtered digital signal) is greater than the threshold for the standard deviation. The last value is a value lastly output by the controller before determining that the standard deviation is greater than the threshold for the standard deviation.

[0082] The signal processing means of the central unit may be configured to perform the statistical evaluation by additionally computing a mean value of the digital signal. Optionally, the signal processing means is configured to perform the statistical evaluation by additionally computing a mean value of the filtered digital signal. The controller may be configured to determine whether the standard deviation is greater than a threshold for the standard deviation. Further, the controller may be configured to ignore the digital signal and use a last mean value of the digital signal for controlling the at least one electrical quantity, during a time period when the standard deviation of the digital signal (optional of the filtered digital signal) is greater than the threshold for the standard deviation. Optionally, the controller may be configured to ignore the filtered digital signal and use a last mean value of the filtered digital signal for controlling the at least one electrical quantity, during a time period when the standard deviation of the digital signal (optional of the filtered digital signal) is greater than the threshold for the standard deviation. The last mean value is a mean value lastly computed before determining that the standard deviation is greater than the threshold for the standard deviation.

[0083] Optionally, the controller is configured to determine whether the standard deviation is greater than a threshold for the standard deviation. The controller may

be configured to ignore the filtered digital signal and use a last value of the filtered digital signal for controlling the at least one electrical quantity, during a time period when the standard deviation of the digital signal (optional of the filtered digital signal) is greater than the threshold for the standard deviation. The last value of the filtered digital signal is a value of the filtered digital signal lastly received before determining that the standard deviation is greater than the threshold for the standard deviation.

[0084] The control IC may be configured to receive the threshold for the standard deviation from outside (e.g. from a user). Optionally, the control IC is configured to receive the threshold for the standard deviation from a microcontroller outside the control IC. For example, the control IC may be configured to receive the threshold for the standard deviation from the central unit.

[0085] The signal processing means of the central unit may comprise a statistics module configured to perform the statistical evaluation. The statistics module may be configured to be turned on and off from outside. Optionally, the statistics module is configured to be turned on and off by a user. In other words, the statistics module may be triggered by a user to be turned on and off.

[0086] Optionally, the statistics module may be configured to be triggered by a user to reset the statistical evaluation (e.g. after a load jump). The signal processing means may be configured to receive information (e.g. a parameter) on a filter length of the moving average filter from a user.

[0087] The statistics module of the signal processing means of the central unit may be configured to be turned on and off from the operating device, optionally from the microcontroller of the operating device. In other words, the statistics module may be triggered by the operating device, optionally by the microcontroller of the operating device to be turned on and off.

[0088] Optionally, the statistics module may be configured to be triggered by the operating device, optionally by the microcontroller of the operating device, to reset the statistical evaluation. The signal processing means may be configured to receive information (e.g. a parameter) on a filter length of the moving average filter from the operating device, optionally from the microcontroller of the operating device.

[0089] The central unit may be configured to provide the statistical evaluation to outside. Optionally, the central unit may be configured to provide the statistical evaluation to a user. For this, the central unit may comprise or be configured to be connected to a display on which the statistical evaluation may be displayed. Optionally, the display is part of the central unit. The central unit may be a central control unit of the lighting system. The central unit may be configured to receive information on performing the statistical evaluation from outside, optional from a user. Optionally, the central unit is configured to receive information on a number of samples of the digital signal to be used for the statistical evaluation from outside, optional from a user.

[0090] The central unit may be configured to provide the statistical evaluation to the optional microcontroller of the operating device. The central unit is configured to receive information on performing the statistical evaluation from the microcontroller of the operating device. Optionally, the central unit is configured to receive information on the number of samples of the digital signal to be used for the statistical evaluation from the microcontroller.

[0091] Optionally, the at least one electrical quantity is at least one of the following: an output voltage of the optional AC/DC converter (e.g. the AC/DC converter is a power factor correction (PFC) circuit) of the electrical supply circuit, an output current of the optional AC/DC converter (e.g. a PFC circuit), an output voltage of the optional DC/DC converter of the electrical supply circuit, and an output current of the optional DC/DC converter.

[0092] Optionally, the lighting system comprise one or more additional operating devices. At least one of the one or more additional operating devices is or may be implemented as the operating device of the lighting system, as outlined above. The central unit may be configured to communicate and optionally control the operating device and the one or more additional operating devices.

[0093] The lighting system may be a luminaire that comprises lighting means. The lighting means are optionally at least one light emitting diode (LED). The operating device of the lighting system (luminaire) may be configured to operate the lighting means.

[0094] The lighting system according to the fourth aspect of the invention achieves the same advantages as the control system according to the first aspect of the invention.

[0095] In order to achieve the lighting system according to the fourth aspect of the invention, some or all of the above described optional features may be combined with each other.

[0096] According to a fifth aspect of the invention, a method for controlling an electrical supply circuit for electrically supplying lighting means is provided. Optionally, the lighting means are at least one light emitting diode (LED). The method comprises converting a measurement of at least one electrical quantity of the electrical supply circuit into a digital signal, performing a statistical evaluation of the digital signal, and controlling, based on the digital signal, the at least one electrical quantity using the statistical evaluation of the digital signal.

[0097] Optionally, the method may be performed by a control IC. The control IC may be part of a control system for controlling an electrical supply circuit for electrically supplying lighting means (e.g. LEDs). For example, the control IC may be the control IC of the control system according to the first aspect of the invention.

[0098] Alternatively, the steps of converting and controlling may be performed by a control IC and the step of signal processing, e.g. performing a statistical evaluation, of the digital signal may be performed by a microcontroller. The control IC and the microcontroller may

form or may be part of a control system for controlling an electrical supply circuit for electrically supplying lighting means (e.g. LEDs). For example, the control IC and the microcontroller may be the control IC and optional microcontroller, respectively, of the control system according to the first aspect of the invention.

[0099] Alternatively, the steps of converting and controlling may be performed by a control IC and the step of signal processing, e.g. performing a statistical evaluation, of the digital signal may be performed by a central unit. The control IC may be part of an operating device of a lighting system and the central unit may be part of the lighting system (the central unit and the operating device are separate entities). For example, the control IC may be the control IC of the operating device of the lighting system according to the fourth aspect of the invention and the central unit may be the central unit of the lighting system according to the fourth aspect of the invention.

[0100] Optionally, the method comprises filtering, using a moving average filter, the digital signal. The method may comprise performing the statistical evaluation by statistically evaluating the filtered digital signal.

[0101] Optionally, the method comprises controlling, based on the digital signal, the at least one electrical quantity using the filtered digital signal and the statistical evaluation of the digital signal.

[0102] The method may comprise performing the statistical evaluation by computing a standard deviation of the digital signal. Optionally, the method comprises performing the statistical evaluation by computing a standard deviation of the filtered digital signal.

[0103] Optionally, the method comprises computing one or more additional statistical values, such as mean value, minimum value, maximum value, etc., of the digital signal or the filtered digital signal. That is, the method may comprise computing one or more additional statistical values, such as mean value, minimum value, maximum value, etc., of the values or data points of the digital signal or the filtered digital signal (e.g. of a certain time period).

[0104] Optionally, the method comprises determining whether the standard deviation is greater than a threshold for the standard deviation, and keeping an output of a controller, which is used for controlling the at least one electrical quantity, constant at a last value, during a time period when the standard deviation of the digital signal (optional of the filtered digital signal) is greater than the threshold for the standard deviation. The last value is a value lastly output by the controller before determining that the standard deviation is greater than the threshold for the standard deviation.

[0105] The method may comprise performing the statistical evaluation by additionally computing a mean value of the digital signal. Optionally, the method comprises performing the statistical evaluation by additionally computing a mean value of the filtered digital signal. The method may comprise determining whether the standard

deviation is greater than a threshold for the standard deviation. Further, the method may comprise ignoring the digital signal and using a last mean value of the digital signal for controlling the at least one electrical quantity, during a time period when the standard deviation of the digital signal (optional of the filtered digital signal) is greater than the threshold for the standard deviation. Optionally, the method comprises ignoring the filtered digital signal and using a last mean value of the filtered digital signal for controlling the at least one electrical quantity, during a time period when the standard deviation of the digital signal (optional of the filtered digital signal) is greater than the threshold for the standard deviation. The last mean value is a mean value lastly computed before determining that the standard deviation is greater than the threshold for the standard deviation.

[0106] Optionally, the method comprises determining whether the standard deviation is greater than a threshold for the standard deviation. The method may comprise ignoring the filtered digital signal and using a last value of the filtered digital signal for controlling the at least one electrical quantity, during a time period when the standard deviation of the digital signal (optional of the filtered digital signal) is greater than the threshold for the standard deviation. The last value of the filtered digital signal is a value of the filtered digital signal lastly received before determining that the standard deviation is greater than the threshold for the standard deviation.

[0107] The step of controlling based on the digital signal may be performed by a control IC and the method may comprise receiving, by the control IC, the threshold for the standard deviation from outside. Optionally, the method may comprise receiving, by the control IC, the threshold for the standard deviation from a microcontroller.

[0108] The method may comprise performing, by a statistics module of signal processing means, the statistical evaluation. The method may comprise turning on and off the statistics module of the control IC from outside. Optionally, the method comprises turning on and off the statistics module of the control IC by a user.

[0109] The method may comprise resetting, from outside, optionally by a user, the statistical evaluation of the statistics module (e.g. after a load jump). The method may comprise receiving, by signal processing means, information (e.g. a parameter) on a filter length of the moving average filter from outside, optionally from a user.

[0110] The method may comprise performing, by a statistics module of signal processing means of a control IC, the statistical evaluation, and turning on and off, by a microcontroller, the statistics module. The control IC and the microcontroller may form or be part of a control system. The method may comprise resetting, by the microcontroller, the statistical evaluation of the statistics module. The method may comprise receiving, from the microcontroller, information (e.g. a parameter) on a filter length of the moving average filter.

[0111] The method may be performed by a control sys-

tem and the method may comprise providing, by the control system, the statistical evaluation to outside. Optionally, the method comprises providing, by the control system, the statistical evaluation to a user. The method may comprise receiving, by the control system, information on performing the statistical evaluation from outside, optional from a user. Optionally, the method may comprise receiving, by the control system, information on a number of samples of the digital signal to be used for the statistical evaluation from outside, optional from a user.

[0112] The method may comprise performing, by signal processing means of a control IC, the statistical evaluation. The method may comprise providing, by the control IC, the statistical evaluation to a microcontroller. The method may comprise receiving, by a control IC, information on performing the statistical evaluation, optional on the number of samples of the digital signal to be used for the statistical evaluation, from the microcontroller. The control IC and the microcontroller may form or be part of a control system.

[0113] Optionally, the at least one electrical quantity is at least one of the following: an output voltage of an AC/DC converter (e.g. the AC/DC converter is a power factor correction (PFC) circuit), an output current of an AC/DC converter (e.g. a PFC circuit), an output voltage of a DC/DC converter, and an output current of a DC/DC converter.

[0114] The above description with regard to the control system according to the first aspect, the operating device according to the second aspect and the lighting system according to the fourth aspect of the invention is also valid for the method according to the fifth aspect of the invention.

[0115] The method according to the fifth aspect of the invention achieves the same advantages as the control system according to the first aspect of the invention.

[0116] In order to achieve the method according to the fifth aspect of the invention, some or all of the above described optional features may be combined with each other.

[0117] 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.

[0118] 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);

Figure 2 shows an example of waveforms of a ripple of an electrical quantity of an electrical supply circuit and a digital signal of the ripple

over time;

Figure 3 shows an example of waveforms of a ripple of an electrical quantity of an electrical supply circuit and a digital signal of the ripple over time;

Figure 4 shows a block diagram of a control system according to an embodiment of the invention;

Figure 5 shows an example of a waveform of a ripple of an electrical quantity of an electrical supply circuit over time and corresponding results of a statistical evaluation performed, based on a digital signal of the electrical quantity, by a control system according to an embodiment of the invention;

Figure 6 shows an example of a waveform of a digital signal of a ripple of an electrical quantity of an electrical supply circuit over time and a corresponding output of a control IC of a control system according to an embodiment of the invention for controlling the electrical supply circuit; and

Figure 7 shows a block diagram of a luminaire according to an embodiment of the invention.

[0119] In the Figures, corresponding elements have the same reference signs.

[0120] **Figure 4** shows a block diagram of a control system according to an embodiment of the invention. The control system 1 of **Figure 4** is an example of the control system according to the first aspect of the invention. Thus, the description with regard to the control system according to the first aspect is correspondingly valid for the control system 1 of **Figure 4**.

[0121] The control system of **Figure 4** is a control system for controlling an electrical supply circuit for electrically supplying lighting means. The lighting means may optionally be at least one light emitting diode (LED), i.e. one or more LEDs. The present disclosure is not limited to LEDs as lighting means. Thus, in addition or alternatively other lighting means types may be used. The control system 1 comprises an analog-to-digital-converter 2 (ADC), signal processing means 3 and a controller 4. The control system 1 may comprise a control integrated circuit (control IC) that comprises the ADC 2 and the controller 4. That is, the ADC 2 and the controller 4 may be part of the control IC of the control system 1. The control IC may be an application specific integrated circuit (ASIC) or a field programmable gate array (FPGA).

[0122] According to an alternative, the control IC of the control system 1 may comprise the signal processing means 3. That is, the ADC 2, the signal processing means 3 and the controller 4 may be part of the control IC of the

control system 1.

[0123] According to another alternative, a microcontroller of the control system 1 may comprise the signal processing means 3. That is, the signal processing means 3 may be part of the microcontroller of the control system, while the ADC 2 and the controller 4 may be part of the control IC of the control system 1. Optionally, the aforementioned alternatives may be combined with each other.

[0124] The control system 1 may be configured to control the electrical supply circuit according to a control of at least one electrical quantity EQ, i.e. one or more electrical quantities, of the electrical supply circuit. In the following, the control system 1 of **Figure 4** is described with regard to the control system 1 controlling one electrical quantity EQ of the electrical supply circuit. This description is correspondingly valid, in case the control system 1 controls more than one electrical quantity EQ of the electrical supply circuit.

[0125] The electrical quantity EQ of the electrical supply circuit may be for example a voltage providable by an optional voltage supply circuit (e.g. in form of an AC/DC converter, optionally being a PFC circuit, or in form of a DC/DC converter) of the electrical supply circuit or a current providable by an optional current source (e.g. in form of an AC/DC converter, optionally being a PFC circuit, or in form of a DC/DC converter) of the electrical supply circuit. The optional voltage supply circuit is a controllable voltage supply circuit controllable by the control system 1. The optional current source is a controllable current source controllable by the control system 1.

[0126] The optional voltage supply circuit may be or may comprise an actively switched AC/DC converter with at least one switch (optionally being an actively switched PFC circuit) and/or an actively switched DC/DC converter with at least one switch. The optional current source may be or may comprise an actively switched AC/DC converter with at least one switch (optionally being an actively switched PFC circuit) and/or an actively switched DC/DC converter with at least one switch.

[0127] The control system 1 may be configured to control switching of the at least one switch of the respective actively switched AC/DC converter by generating a control signal, based on a control of the respective electrical quantity EQ providable by the respective actively switched AC/DC converter, and providing the control signal to the at least one switch. Correspondingly, the control system 1 may be configured to control switching of the at least one switch of the respective actively switched DC/DC converter by generating a control signal, based on a control of the respective electrical quantity EQ providable by the respective actively switched DC/DC converter, and providing the control signal to the at least one switch.

[0128] The control system 1, in particular the control IC and, thus, the ADC 2, is configured to receive a measurement of the electrical quantity EQ and convert the measurement of the electrical quantity into a digital signal

DS. The control system 1, in particular the control IC and, thus, the ADC 2, may be configured to receive the measurement of the electrical quantity EQ in form of an analog signal that may be referred to as measurement signal indicating or representing the electrical quantity EQ. The ADC 2 is configured to provide the digital signal DS to the signal processing means 3. In case the signal processing means 3 is part of the optional microcontroller of the control system 1, the control IC 1 (comprising the ADC 2) may be configured to provide the digital signal DS to the microcontroller and, thus, to the signal processing means 3.

[0129] The signal processing means 3 may be configured to process the digital signal DS. In particular, the signal processing means 3 may be configured to perform a statistical evaluation of the digital signal DS and provide the statistical evaluation of the digital signal DS to the controller 4. That is, the signal processing means 3 may be configured to statistically evaluate the digital signal DS. The signal processing means 3 may be configured to filter, using a moving average filter 3a, the digital signal DS. This generates a filtered digital signal DS_f. The signal processing means 3 may be configured to provide the filtered digital signal DS_f to the controller 4.

[0130] Optionally, in case the optional microcontroller of the control system 1 comprises the signal processing means for performing the statistical evaluation of the digital signal DS, the control IC 1 may comprise a second signal processing means (not shown in Figure 4), wherein the second signal processing means is configured to filter, using a moving average filter, the digital signal. The second signal processing means may be configured to provide the filtered digital signal DS_f to the controller 4. Optionally, the second signal processing means may be configured to provide the filtered digital signal DS_f to the signal processing means of the microcontroller and the signal processing means may be configured to perform the statistical evaluation by statistically evaluating the filtered digital signal DS_f received from the second signal processing means. The controller 4 may be configured to control, based on the digital signal DS, the at least one electrical quantity EQ using the filtered digital signal DS_f received from the second signal processing means and the statistical evaluation of the digital signal DS received from the signal processing means of the microcontroller.

[0131] As shown in Figure 4, the signal processing means 3 may be configured to perform the statistical evaluation by computing a standard deviation S2 of the digital signal DS. Optionally, the signal processing means 3 is configured to perform the statistical evaluation by additionally computing a mean value S1 of the digital signal DS. Optionally, the signal processing means 3 may be configured to compute one or more additional statistical values, such as minimum value, maximum value, etc., of the digital signal DS. That is, the signal processing means 3 may be configured to compute one or more additional statistical values, such as minimum value,

maximum value, etc., of the values or data points of the digital signal or the filtered digital signal (e.g. of a certain time period).

[0132] The signal processing means 3 may comprise a statistics module 3b configured to perform the statistical evaluation; wherein the statistics module 3b may be configured to be turned on and off from outside the control IC 1, optional by a user. In case the control IC of the control system 1 comprises the signal processing means 3, the statistics module 3b may be configured to be turned on and off from a microcontroller of the control system 1.

[0133] Optionally, the signal processing means 3 may use the filtered digital signal DS_f for performing the statistical evaluation. In other words, the signal processing means 3 may be configured to perform the statistical evaluation of the digital signal DS by statistically evaluating the filtered digital signal DS_f. In this case, the description with regard to processing the digital signal DS for a statistical evaluation and the result of such statistical evaluation is correspondingly valid when statistically evaluating the filtered digital signal DS_f for a statistical evaluation of the digital signal DS.

[0134] The controller 4 is configured to control the electrical quantity EQ using the filtered digital signal DS_f and the statistical evaluation of the digital signal DS, e.g. the standard deviation S2 of the digital signal DS and optionally the optional mean value S1 of the digital signal DS, provided by the signal processing means 3. In particular, the controller 4 may be configured to perform a control of the electrical quantity EQ by using the filtered digital signal DS_f as an input of the control. For example the controller may be configured to perform a feedback control of the electrical quantity by comparing the filtered digital signal DS_f with a reference value or reference variable.

[0135] According to an embodiment, the ADC 2 may convert measurements of two electrical quantities to two digital signals, wherein a first digital signal of the two digital signals represents a first electrical quantity of the two electrical quantities and a second digital of the two digital signals represents a second electrical quantity of the two electrical quantities. The signal processing means 3 may filter the two digital signals generating a first filtered digital signal for the first electrical quantity and a second filtered digital signal for the second electrical quantity and statistically evaluate the two digital signals, as outlined above for the digital signal DS. The controller 4 may then perform a feedforward control of e.g. the first electrical quantity by using the second filtered digital signal as an input of the feedforward control. For example, the first electrical quantity may be a current providable by a current source, e.g. in the form of DC/DC converter, of the electrical supply circuit to the lighting means, and the second electrical quantity may be a voltage (supply voltage) providable by a voltage supply circuit (e.g. in the form of an AC/DC converter (optionally a PFC circuit) or a DC/DC converter) of the electrical supply circuit to the current source.

[0136] The controller 4 may be configured to use the statistical evaluation of the digital signal DS, e.g. the standard deviation S2 and optionally the optional mean value S1, for determining or detecting disturbances of the electrical quantity EQ and reacting thereto, i.e. when disturbances (that are not negligible) are determined or detected. That is, the controller 4 may be configured to adapt the control, using the filtered digital signal DS_f, of the electrical quantity EQ depending on the statistical evaluation of the digital signal DS. Thus, the controller 3 may be configured to adapt the control of the electrical quantity EQ in case disturbances of the electrical quantity EQ are determined or detected based on the statistical evaluation of the digital signal DS.

[0137] Since the filtered DS_f is generated from the digital signal DS, the control performable by the controller 4 may be described as a control, based on the digital signal DS, using the statistical evaluation of the digital signal DS and the filtered digital signal DS_f. In other words, the controller 4 may be configured to control the electrical quantity EQ, based on the digital signal DS, using the filtered digital signal DS_f and the statistical evaluation of the digital signal DS. The control system 1 may be configured to control, based on the output ctrl_out of the controller 4, the electrical supply circuit. In particular the control system 1 may be configured to control, based on the output ctrl_out of the controller 4, the part or component of the electrical supply circuit that is associated with the electrical quantity EQ. For example, in case the electrical quantity EQ is a current of a current source (controllable current source) of the electrical supply circuit, then the control system 1 may be configured to control, based on the output ctrl_out of the controller 4, the current source. In case the electrical quantity EQ is for example a voltage of a voltage supply circuit (controllable voltage supply circuit) of the electrical supply circuit, then the control system 1 may be configured to control, based on the output ctrl_out of the controller 4, the voltage supply circuit.

[0138] The control system 1 may be configured to generate, based on the ctrl_out of the controller 4, a control signal (e.g. a PWM signal) for controlling the electrical supply circuit, e.g. a part or component of the electrical supply circuit associated with the electrical quantity EQ. The control system 1, optionally the control IC, may comprise a driver logic or driver unit for generating the control signal, wherein the controller 4 is configured to provide its output ctrl_out (control output) to the driver logic (not shown in Figure 4).

[0139] The controller 4 may be configured to determine whether the standard deviation S2 is greater than a threshold for the standard deviation. When the standard deviation S2 is greater than the threshold for the standard deviation, the controller 4 may determine that disturbances of the electrical quantity EQ are present that negatively impact or distort the digital signal DS and, thus, the control of the electrical EQ based on the filtered digital signal DS_f. The threshold for the standard deviation may be

adjustable. For example, the threshold for the standard deviation may be set or changed by a user. The smaller or lower the threshold, the smaller or lower the disturbances, e.g. the smaller the ripple change or variation, of the electrical quantity EQ that are detectable or may be determined by the controller 4 and vice versa. The controller 4 may be configured to monitor the standard deviation of the digital signal.

[0140] Figure 5 shows an example of a waveform of a ripple of an electrical quantity of an electrical supply circuit over time and corresponding results of a statistical evaluation performed, based on a digital signal of the electrical quantity, by a control system according to an embodiment of the invention. In particular, Figure 5 shows an example of the waveform of a ripple of the electrical quantity EQ provided to the control system 1 of Figure 4. The electrical quantity EQ may be a direct electrical quantity (e.g. a direct current (DC current) or a direct voltage (DC voltage)) having a ripple. Figure 5 shows such a ripple. Further Figure 5 shows, the waveform of the mean value S1 of the digital signal DS of the electrical quantity EQ optionally computed by the signal processing unit 3 and the waveform of the standard deviation S2 of the digital signal DS computed by the signal processing unit 3.

[0141] As shown in Figure 5, the disturbances of the electrical quantity EQ corresponding to an increase of the amplitude of the ripple of the signal or waveform representing the electrical quantity EQ cause an increase of the standard deviation S2 of the digital signal DS representing the electrical quantity EQ. Thus, in case the threshold for the standard deviation is set so that its value is lower or smaller than the value of the standard deviation S2 during the time period between the time t1 and t2, when the disturbances of the electrical EQ are present, the controller 4 may be configured to determine or detect the presence of these disturbances. As shown in the top graph of Figure 5, at the time t1 disturbances of the electrical quantity EQ occur, which are visible in the analog signal representing the quantity EQ in the form of an increase of the amplitude of the ripple of the signal at the time t1. As a result, the standard deviation S2 of the digital signal, which is converted from the analog signal of the electrical quantity EQ, increases at the time t1, as shown in the bottom graph of Figure 5. When the disturbances of the electrical quantity EQ stop at the time t2 the standard deviation S2 decreases, as shown in the bottom graph of Figure 5.

[0142] According to an embodiment, the controller 4 of the control system 1 of Figure 4 may be configured to keep its output ctrl_out constant at a last value, during a time period when the standard deviation S2 of the digital signal DS is greater than the threshold for the standard deviation. The last value is a value lastly output by the controller 4 before determining that the standard deviation S2 is greater than the threshold for the standard deviation.

[0143] Figure 6 shows an example of a waveform of

a digital signal of a ripple of an electrical quantity of an electrical supply circuit over time and a corresponding output of a control IC of a control system according to an embodiment of the invention for controlling the electrical supply circuit. In particular Figure 6 shows examples of the waveforms of the digital signal DS generated by the ADC 2 and the filtered digital signal DS_f generated by the signal processing means 3 of the control system 1 of Figure 4. Further, Figure 6 shows the waveform of the optional mean value S1 and the standard deviation S2 of the digital signal DS as well as the waveform of the output ctrl_out of the controller 4. In addition, the threshold TrS2 for the standard deviation S2 is exemplarily indicated in Figure 6.

[0144] As shown in Figure 6, between the time t3 and t4 disturbances of the electrical quantity EQ occur that are visible in the digital signal DS and the filtered digital signal DS_f as a ripple amplitude change (ripple amplitude increase) of the respective waveform. As a result of the disturbances, the standard deviation S2 computed by the signal processing means 3 based on the digital signal DS increases between the times t3 and t4 above the threshold TrS2 for the standard deviation S2. Thus, according to the example of Figure 6, the threshold TrS2 for the standard deviation S2 is set so that the disturbances of the electrical quantity exemplarily shown in Figure 6 may be determined or detected by the controller 4.

[0145] Therefore, as shown in Figure 6, the controller 4 keeps its output ctrl_out constant at a last value, during the time period between the times t3 and t4. This time period is a time period when the standard deviation S2 of the digital signal DS is greater than the threshold TrS2 for the standard deviation. The last value is a value lastly output by the controller 4 before determining that the standard deviation S2 is greater than the threshold TrS2 for the standard deviation. For example, it is the value lastly output by the controller 4 before the time t3. Thus, the output ctrl_out of the controller 4 is kept constant during the time period between the time t3 and t4, as shown in Figure 6.

[0146] According to another embodiment, the controller 4 may be configured to ignore the digital signal DS, in particular the filtered digital signal DS_f, and use a last mean value of the digital signal DS for controlling the at least one electrical quantity EQ, during a time period when the standard deviation S2 of the digital signal is greater than the threshold for the standard deviation. The last mean value is the mean value S1 lastly computed by the signal processing means 3 before the controller 4 determines that the standard deviation S2 is greater than the threshold for the standard deviation.

[0147] According to another embodiment, the controller 4 may be configured to ignore the filtered digital signal DS_f and use a last value of the filtered digital signal DS_f for controlling the at least one electrical quantity EQ, during a time period when the standard deviation S2 of the digital signal DS is greater than the threshold for

the standard deviation. The last value of the filtered digital signal DS_f is a value of the filtered digital signal DS_f lastly received by the controller 4 before the controller 4 determines that the standard deviation S2 is greater than the threshold for the standard deviation.

[0148] Thus, the controller 4 may be configured to "freeze", i.e. stop or interrupt, performing the control of the electrical quantity EQ based on the filtered digital signal DS_f, during a time period when the standard deviation S2 of the digital signal DS is greater than the threshold for the standard deviation. That is, the controller 4 may be configured to stop or interrupt its normal control of the electrical quantity EQ during the time period when the standard deviation S2 of the digital signal DS is greater than the threshold for the standard deviation. Thus, the controller 4 may be configured to continue its normal control of the electrical quantity EQ in response to the standard deviation S2 of the digital signal DS decreasing below the threshold for the standard deviation.

[0149] Instead of the normal control, the controller 4 may be configured to do at least one of the following during the time period when the standard deviation S2 of the digital signal DS is greater than the threshold for the standard deviation. For example, the controller 4 may be configured to keep its output ctrl_out constant at the aforementioned last value. The controller 4 may ignore the digital signal DS, in particular the filtered digital signal DS_f, and use the aforementioned last mean value of the digital signal DS for controlling the at least one electrical quantity EQ. The controller 4 may ignore the filtered digital signal DS_f and use the aforementioned last value of the filtered digital signal DS_f for controlling the at least one electrical quantity EQ.

[0150] The control system 1 is configured to receive information from outside (not shown in Figure 4). The control system 1 may be configured to receive the information from a person or user of the electrical supply circuit or the lighting means. The information may comprise the threshold for the standard deviation S2 of the digital signal DS. Thus, the threshold for the standard deviation S2, which is used by the controller 4 for processing the statistical evaluation, in particular for processing the standard deviation S2, of the digital signal DS, may be set or changed from outside the control system 1, e.g. by a person. The information may comprise control parameters for the control of the electrical quantity EQ performable by the controller 4, e.g. a reference value or reference variable for a feedback control. The information may comprise a turn on or turn off instruction for turning on respectively turning off the optional statistics module 3b of the signal processing means 3. This allows activating or deactivating from outside, e.g. by a person, the function regarding the statistical evaluation of the digital signal DS for detecting disturbances of the electrical quantity EQ.

[0151] The information may comprise information on signal processing of the signal processing means 3. For example, the information may comprise information on

the number of samples or data points of the digital signal DS that are to be used for statistically evaluating the digital signal DS. For example, in case of dynamic control processes that are to be controlled by the control system 1 the statistical evaluation of the digital signal may be based on a smaller number of samples of the digital signal DS compared to the case of a static control process to be controlled by the control IC1. For example, dynamic control processes comprise controlling of the electrical quantity EQ in order to control the electrical supply circuit so that light emission of the lighting means is turned on, turned off or dimmed. A static control process may comprise controlling the electrical quantity EQ by performing a feedback control of the electrical quantity with regard to a reference value or variable being kept constant.

[0152] For further details of the control system 1 of Figure 4 reference is made to the above description of the control system according to the first aspect of the invention and the description of Figure 7.

[0153] Figure 7 shows a block diagram of a luminaire according to an embodiment of the invention. The luminaire of Figure 7 is an example of the luminaire according to the third aspect of the invention as described above. Therefore, the above description of the luminaire according to the third aspect is correspondingly valid for the luminaire of Figure 7.

[0154] As shown in Figure 7, the luminaire 16 comprises an operating device 15 and lighting means 10, wherein the operating device 15 is configured to operate the lighting means 10. The lighting means 10 may be one or more LEDs (i.e. at least one LED), as exemplarily shown in Figure 7. The lighting means 10 may be alternatively or additionally any other lighting means type. The operating device 15 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 15.

[0155] As shown in Figure 7, the operating device 15 comprises an electrical supply circuit 7 for electrically supplying the lighting means 10 and a control system 1 for controlling the electrical supply circuit 7. The control system 1 is an example of the control system according to the first aspect and, thus, the description with regard to the control system of the first aspect is correspondingly valid for the control system 1. The control system 1 may be the control system 1 of Figure 4, as described above. As shown in Figure 7, the control system may comprise a control IC 1a and optionally a microcontroller 5. The control IC 1a may be for example an ASIC or a FPGA.

[0156] As outlined above with regard to e.g. Figure 4, according to an alternative, the control IC 1a may comprise the signal processing means of the control system 1. According to another alternative, the microcontroller 5 may comprise the signal processing means of the control system. The signal processing means of the control system 1 are configured to perform a statistical evaluation on the digital signal receivable from the analog digital converter (ADC) of the control IC 1a.

[0157] The electrical supply circuit 7 may comprise a DC/DC converter 9 for providing a current I_{LM} and/or voltage V_{LM} to the lighting means 10 and an AC/DC converter 8 for providing a supply voltage V_{bus} to electrically supply at least the DC/DC converter 9. The AC/DC converter may be configured to perform a power factor correction function (PFC function). That is, the AC/DC converter 8 may be a PFC circuit.

[0158] The AC/DC converter 8 may be an actively switched AC/DC circuit with at least one switch. In case the actively switched AC/DC converter 8 is configured for a PFC function it may be referred to as actively switched PFC circuit with at least one switch. The control IC 1a of the control system 1 may be configured to control switching of the at least one switch of the actively switched AC/DC converter 8. Optionally, the actively switched AC/DC converter 8 may comprise a rectifier circuit and an actively switched DC/DC converter with at least one switch. Optionally, the DC/DC converter 9 may be an actively switched DC/DC converter with at least one switch, and the control IC 1a of the control system 1 is configured to control switching of the at least one switch. The DC/DC converter 9 may be a current source (controllable current source) for providing the current I_{LM} to the lighting means. The DC/DC converter 9 may be a voltage source (controllable voltage source) for providing a voltage (e.g. LED voltage) to the lighting means.

[0159] Thus, one or more electrical quantities EQ, which may be provided to the control IC 1a and controlled by the control IC 1a, may be for example the voltage V_{bus} providable by the AC/DC converter 8 (e.g. PFC circuit), a current providable by the AC/DC converter 8 (e.g. PFC circuit), the current I_{LM} providable by the DC/DC converter 9 and/or the voltage V_{LM} providable by the DC/DC converter 9.

[0160] The control IC 1a of the control system 1 may be configured to control the voltage V_{bus} or the current providable by the AC/DC converter 8 by controlling the AC/DC converter 8. The control IC 1a of the control system 1 may be configured to control the current I_{LM} or voltage V_{LM} providable by the DC/DC converter 9 by controlling the DC/DC converter 9.

[0161] 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 (MOSFETs); bipolar junction transistors (BJTs); insulated gate bipolar transistors (IGBTs) etc.

[0162] The electrical supply circuit 7, optionally the DC/DC converter 9, may comprise a measurement unit for measuring the current I_{LM} or the voltage V_{LM} providable by the DC/DC converter 9 (not shown in Figure 7). The control IC 1a of the control system 1, in particular the ADC 2 of the control IC 1a, may be configured to receive the measurement of the current I_{LM} and/or the voltage V_{LM} . The electrical supply circuit 7, optionally the

AC/DC converter 8, may comprise a measurement unit for measuring the supply voltage V_{bus} or the current providable by the AC/DC converter 8 (not shown in Figure 7). The control IC 1a of the control system 1, in particular the ADC 2 of the control IC 1a, may be configured to receive the measurement of the supply voltage V_{bus} and or the current of the AC/DC converter 8. A measurement unit for measuring current may comprise or may be a shunt resistor. A measurement unit for measuring voltage may comprise or may be a voltage divider and/or magnetically coupled inductors.

[0163] Optionally, the operating device 15, in particular the electrical supply circuit 7, may comprise a rectification and/or filter circuit (not shown in Figure 7). This rectification and/or filter circuit may comprise filter means (e.g. EMI filter) and/or rectifier means. The rectification and/or filter circuit may be implemented in any way known in the art. The optional rectification and/or filter circuit, the AC/DC converter 8 and the DC/DC converter 9 may form the electrical energy supply circuit 7 for providing electrical energy from an external electrical energy source 6, e.g. mains, to the lighting means 10. Optionally, the rectification and/or filter circuit (e.g. rectification means) may at least partly be part of the AC/DC converter 8. The AC/DC converter 8 may be electrically supplied from the external electrical energy source 6 (in case the optional rectification and/or filter circuit is not present) or from the optional rectification and/or filter circuit. The optional rectification and/or filter circuit may be supplied from the external electrical energy source 6.

[0164] The microcontroller 5 may be configured to provide information to the control IC 1. The information may be as outlined above with regard to information receivable by the control IC 1 of Figure 4. The microcontroller 5 may be configured to communicate with outside the operating device 15, e.g. an external device arranged outside the operating device 15. Such an external device may be part of the luminaire 16 or outside the luminaire 16. The microcontroller 5 may receive the information from a person or user of the operating device 15 or the luminaire 16.

[0165] As outlined above, according to an alternative, the control IC 1a may comprise the signal processing means of the control system 1. The control IC 1 may be configured to provide the statistical evaluation of the digital signal of the at least one electrical quantity of the electrical supply circuit 7 provided to the control IC 1a (e.g. a standard deviation of the digital signal and optionally a mean value of the digital signal) to the microcontroller 5. The microcontroller 5 may be configured to communicate this information (i.e. the statistical evaluation of the digital signal) received from the control IC 1a to outside the operating device 15, optionally outside the luminaire 16.

[0166] According to another alternative, the microcontroller 5 may comprise the signal processing means of the control system 1. In this case, the microcontroller 5 may be configured to communicate the information pro-

vided or computed by the signal processing means (i.e. the statistical evaluation of the digital signal) to outside the operating device 15, optionally outside the luminaire 16.

[0167] The operating device 15 or the luminaire 16 may comprise a display that is configured to display the information provided by the microcontroller 5 to outside, e.g. results of statistical evaluations of one or more electrical quantities performable by the signal processing means of the control system 1 (this options apply for both aforementioned alternatives). This information providable by the microcontroller 5 to outside the operating device 15, optional outside the luminaire 16, may be used by a person for an error analysis of the operating device 15, optionally of the luminaire 16. For example based on a statistical evaluation of the voltage V_{bus} providable by the AC/DC converter 8 an aging of one or more capacitors (e.g. electrolytic capacitors) of the AC/DC converter 8 and, thus, of the AC/DC converter 8 may be determined. Aging of the AC/DC converter 8 (e.g. of the one or more capacitors) may result in a decrease of the quality of the voltage V_{bus} which may result in a higher or greater ripple of the current I_{LM} providable by the DC/DC converter 9.

[0168] The operating device 15 may comprise a communication interface 13 for communication to outside the operating device 15. Outside the operating device 15 may mean outside the luminaire 16. The control system 1, in particular the microcontroller 5, may be configured to communicate via the communication interface 13. The control IC 1 may be configured to communicate information or data, e.g. in case of the first aforementioned alternative statistical evaluation results computed by the signal processing means of the control IC 1, to the microcontroller 5. The microcontroller 5 may communicate information received from the control IC 1 and/or own generated information, e.g. in case of the second aforementioned alternative statistical evaluation results computed by the signal processing means of the microcontroller 5, to the outside of the operating device 15 or of the luminaire 16.

[0169] The communication interface 13 may be configured to communicate wirelessly (e.g. via Bluetooth) and/or wire bound. The communication 13 interface may be a bus interface configured for being electrically connected to a bus 12. The bus 12 may be a wired bus. The bus 12 may be a digital bus, optionally a digital data bus. The bus 12 may be part of the luminaire 16. The bus 12 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 12 may be any other known bus type, such as a Distributed Systems Interface (DSI) bus. Thus, the communication interface 13 may be a DALI interface, a DALI-2 interface, a DSI interface etc.

[0170] As shown in Figure 7, the microcontroller 5 may optionally be electrically connected to the communication interface 13 via a galvanic isolation circuit 14. For exam-

ple, the isolation circuit 14 may comprise one or more optocouplers, one or more transformers etc. The microcontroller 5 may be configured to communicate via the communication interface 13 with outside the operating device 15, i.e. with an external unit outside the operating device 15. Outside the operating device 15 may optionally mean outside the luminaire 16.

[0171] Optionally, the operating device 15 may comprise a low voltage power supply 11 for electrically supplying the microcontroller 5, the control IC 1, and the communication interface 13. The low voltage power supply 11 may be electrically supplied with the supply voltage V_{bus} providable by the PFC circuit 8.

[0172] For a description of the ADC, the signal processing means and the controller of the control system 1; reference is made to the description of the control system of the first aspect of the invention and the description with regard to Figures 4, 5 and 6.

[0173] For further details of the control system 1 of Figure 7; reference is made to the above description of the control system according to the first aspect of the invention as well as the above description of Figures 4, 5 and 6. For further details of the operating device 15 of Figure 7; reference is made to the above description of the operating device according to the second aspect of the invention. For further details of the luminaire 16 of Figure 7 reference is made to the above description of the luminaire according to the third aspect of the invention.

[0174] According to another alternative, the signal processing means may be part of a central unit outside the operating device 15 (not shown in Figure 7). The above description of Figure 7 is correspondingly valid for this case. The central unit may be part of the luminaire 16. Alternatively, the central unit may be arranged outside the luminaire 16. The central unit and the operating device 15 may form a lighting system (that may optionally be the luminaire 16). The control system 1, in particular the microcontroller 5, may be configured to communicate with the central unit. For example, this communication may be via a wired bus (e.g. the bus 12) or may be wireless (e.g. via Bluetooth). Optionally, this communication may be via the communication interface 13.

[0175] The central unit may comprise or be configured to be connected to a display that is configured to display the information received from outside (e.g. from the control system 1, in particular the microcontroller 5) and/or own generated information (e.g. results of statistical evaluations of one or more electrical quantities of the electrical supply circuit 7 performable by the signal processing means of the central unit).

[0176] The central unit may be a central control unit of the lighting system. The central unit may be configured to receive information on performing the statistical evaluation from outside, optional from a user. Optionally, the central unit is configured to receive information on a number of samples of the digital signal to be used for the statistical evaluation from outside, optional from a user.

[0177] For further information on the alternative re-

garding the central unit and, thus, on the central unit reference is made to the description of the lighting system according to the fourth aspect of the invention.

[0178] Optionally, the above described different alternatives with regard to arranging signal processing means for performing a statistical evaluation of a digital signal may be arbitrary combined with each other.

[0179] 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 system (1) for controlling an electrical supply circuit (7) for electrically supplying lighting means (10), optional at least one light emitting diode, LED; wherein
 - the control system (1) comprises a control integrated circuit (1a), control IC, comprising an analog-to-digital-converter (2), ADC, for converting a measurement of at least one electrical quantity (EQ) of the electrical supply circuit (7) into a digital signal (DS);
 - the control system (1) comprises signal processing means (3) for processing the digital signal (DS); and
 - the control IC (1a) comprises a controller (4) for controlling the at least one electrical quantity (EQ); wherein
 - the signal processing means (3) is configured to perform a statistical evaluation of the digital signal (DS); and
 - the controller (4) is configured to control, based on the digital signal (DS), the at least one electrical quantity (EQ) using the statistical evaluation of the digital signal (DS).
2. The control system (1) according to claim 1, wherein
 - the control IC (1a) comprises the signal processing means (3).
3. The control system (1) according to claim 1, wherein
 - the control system (1) comprises a microcontroller (5) that comprises the signal processing means (3).
4. The control system (1) according to any one of the previous claims, wherein

- the signal processing means (3) is configured to
 - filter, using a moving average filter (3a), the digital signal (DS), and
 - optionally perform the statistical evaluation by statistically evaluating the filtered digital signal (DS_f).
- 5. The control system (1) according to claim 4, wherein
 - the controller (4) is configured to control, based on the digital signal (DS), the at least one electrical quantity (EQ) using the filtered digital signal (DS_f) and the statistical evaluation of the digital signal (DS).
- 6. The control system (1) according to any one of the previous claims, wherein
 - the signal processing means (3) is configured to perform the statistical evaluation by computing a standard deviation (S2) of the digital signal (DS), optional of the filtered digital signal (DS_f).
- 7. The control system (1) according to claim 6, wherein
 - the controller (4) is configured to
 - determine whether the standard deviation (S2) is greater than a threshold for the standard deviation, and
 - keep its output (ctrl_out) constant at a last value, during a time period when the standard deviation (S2) of the digital signal is greater than the threshold for the standard deviation, wherein
 - the last value is a value lastly output by the controller (4) before determining that the standard deviation (S2) is greater than the threshold for the standard deviation.
- 8. The control system (1) according to claim 6, wherein
 - the signal processing means (3) is configured to perform the statistical evaluation by additionally computing a mean value (S1) of the digital signal (DS), optional of the filtered digital signal (DS_f); and
 - the controller (4) is configured to
 - determine whether the standard deviation (S2) is greater than a threshold for the standard deviation, and
 - ignore the digital signal (DS), optional filtered digital signal (DS_f), and use a last mean value of the digital signal (DS), optional filtered digital signal (DS_f), for controlling the at least one electrical quantity (EQ), during a time period when the standard deviation (S2) of the digital signal is greater than the threshold for the standard deviation, wherein
 - the last mean value is a mean value (S1) lastly computed before determining that the standard deviation (S2) is greater than the threshold for the standard deviation.
- 9. The control system (1) according to claim 6 when depending on claim 4 or 5, wherein
 - the controller (4) is configured to
 - determine whether the standard deviation (S2) is greater than a threshold for the standard deviation, and
 - ignore the filtered digital signal (DS_f) and use a last value of the filtered digital signal (DS_f) for controlling the at least one electrical quantity (EQ), during a time period when the standard deviation (S2) of the digital signal is greater than the threshold for the standard deviation, wherein
 - the last value of the filtered digital signal (DS_f) is a value of the filtered digital signal (DS_f) lastly received before determining that the standard deviation (S2) is greater than the threshold for the standard deviation.
- 10. The control system (1) according to any one of claims 7 to 9, wherein the control IC (1a) is configured to receive the threshold for the standard deviation from outside, optionally from a microcontroller (5) of the control system (1).
- 11. The control system (1) according to any one of the previous claims, wherein
 - the signal processing means (3) comprises a statistics module (3b) configured to perform the statistical evaluation; and
 - the statistics module (3b) is configured to be turned on and off from outside, optional by a user.
- 12. The control system (1) according to claim 11 when depending on claim 2, wherein the statistics module (3b) is configured to be turned on and off from a microcontroller (5) of the control system (1).
- 13. The control system (1) according to any one of the previous claims, wherein
 - the control system (1) is configured to provide the statistical evaluation to outside, optional to

- a user; and/or
 - the control system (1) is configured to receive information on performing the statistical evaluation, optional on a number of samples of the digital signal (DS) to be used for the statistical evaluation, from outside, optional from a user. 5
- 14.** The control system (1) according to claim 13 when depending on claim 2, wherein 10
- the control IC (1a) is configured to provide the statistical evaluation to a microcontroller (5) of the control system (1); and/or
 - the control IC (1a) is configured to receive information on performing the statistical evaluation, optional on the number of samples of the digital signal (DS) to be used for the statistical evaluation, from a microcontroller (5) of the control system (1). 15
- 15.** The control system (1) according to any one of the previous claims, wherein 20
- the at least one electrical quantity (EQ) is at least one of the following 25
 - an output voltage (V_{bus}) of an AC/DC converter, optional power factor correction, PFC, circuit,
 - an output current of an AC/DC converter, optional PFC circuit,
 - an output voltage (V_{LM}) of a DC/DC converter, and 30
 - an output current (I_{LM}) of a DC/DC converter.
- 16.** An operating device (15) for lighting means (10), optional at least one light emitting diode, LED; wherein 35
- the operating device (15) comprises
 - a control system (1) according to any one of the previous claims, and 40
 - an electrical supply circuit (7), optional an AC/DC converter (8) and/or a DC/DC converter (9), for electrically supplying the lighting means (10); and 45
 - the control system (1) is configured to control the electrical supply circuit (7).
- 17.** A luminaire (16) comprising 50
- the operating device (15) according to claim 16; and
 - lighting means (10), optional at least one light emitting diode, LED; wherein
 - the operating device (15) is configured to operate the lighting means (10). 55
- 18.** A lighting system comprising
- an operating device (15) for lighting means (10), optional at least one light emitting diode, LED, and
 - a central unit configured to communicate with the operating device; wherein
 - the operating device (15) comprises an electrical supply circuit (7), optional an AC/DC converter (8) and/or a DC/DC converter (9), for electrically supplying the lighting means (10) and a control IC (1a) for controlling the electrical supply circuit (7);.
 - the control IC (1a) comprises an analog-to-digital-converter (2), ADC, for converting a measurement of at least one electrical quantity (EQ) of the electrical supply circuit (7) into a digital signal (DS), and a controller (4) for controlling the at least one electrical quantity (EQ);
 - the central unit comprises signal processing means (3) for processing the digital signal (DS);
 - the signal processing means (3) is configured to perform a statistical evaluation of the digital signal (DS); and
 - the controller (4) is configured to control, based on the digital signal (DS), the at least one electrical quantity (EQ) using the statistical evaluation of the digital signal (DS).
- 19.** A method for controlling an electrical supply circuit (7) for electrically supplying lighting means (10), optional at least one light emitting diode, LED; wherein
- the method comprises
 - converting a measurement of at least one electrical quantity (EQ) of the electrical supply circuit (7) into a digital signal (DS),
 - performing a statistical evaluation of the digital signal (DS), and
 - controlling, based on the digital signal (DS), the at least one electrical quantity (EQ) using the statistical evaluation of the digital signal (DS).

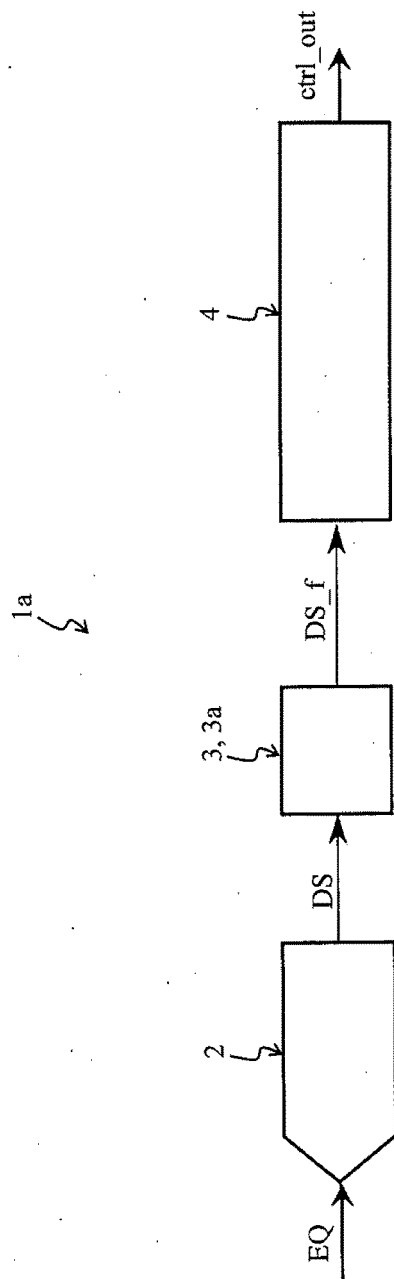


Figure 1

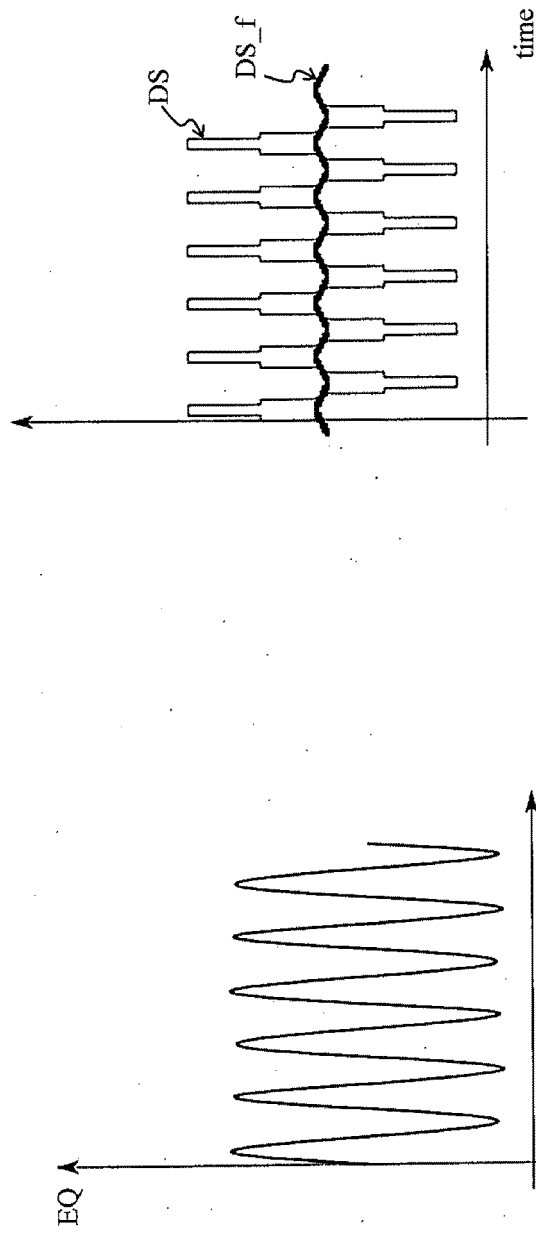


Figure 2

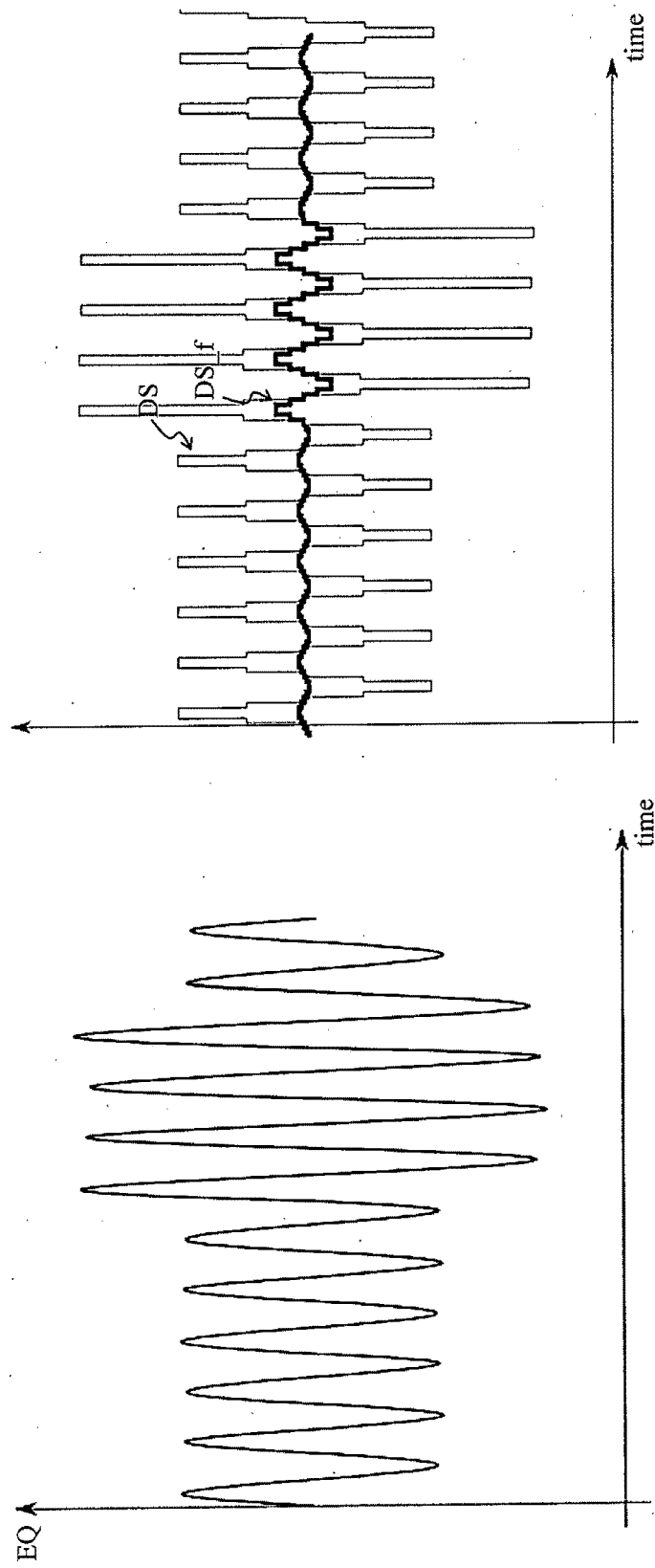


Figure 3

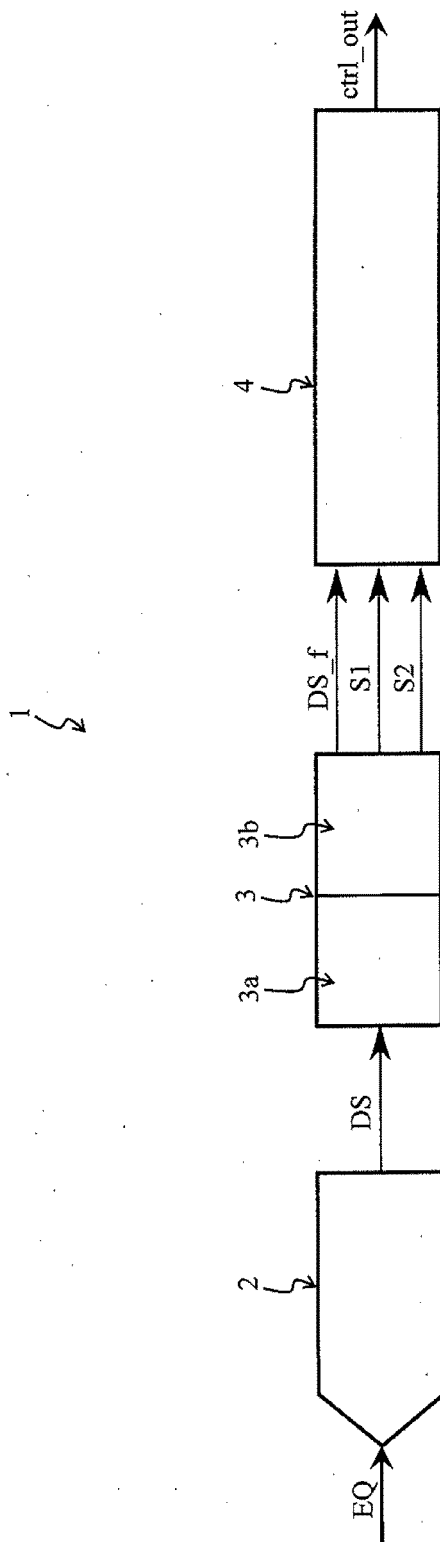


Figure 4

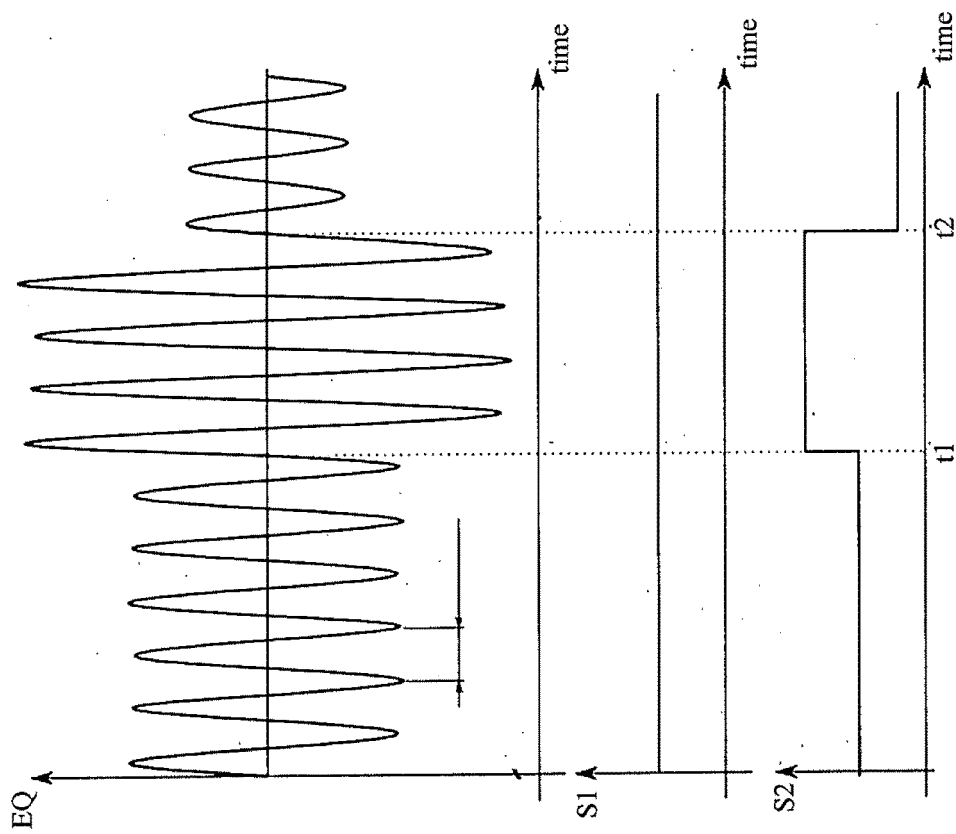


Figure 5

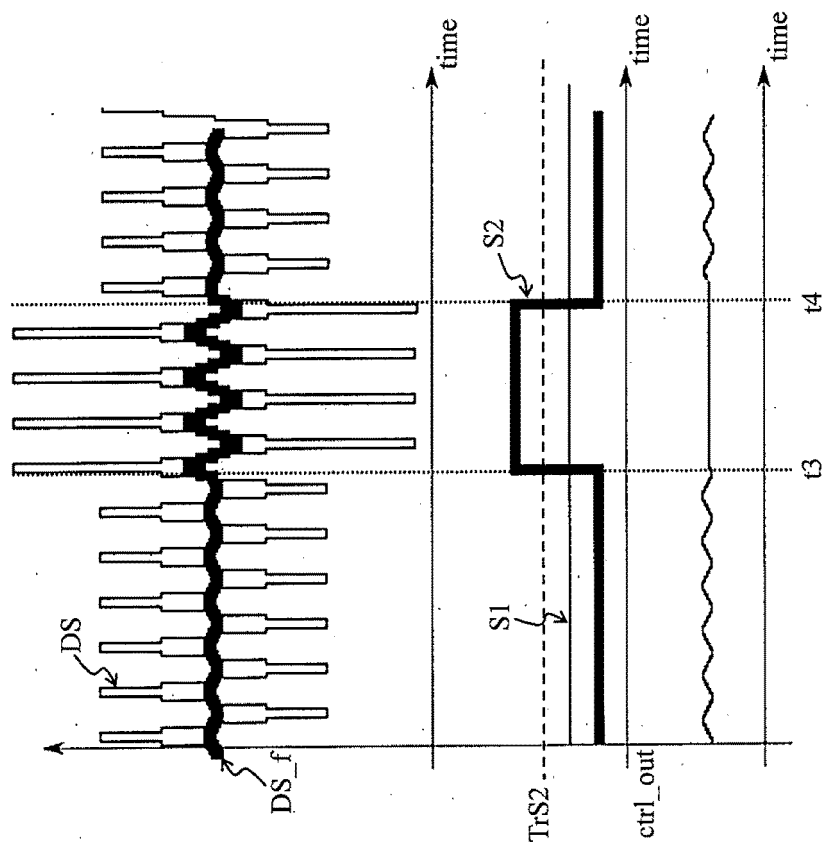


Figure 6

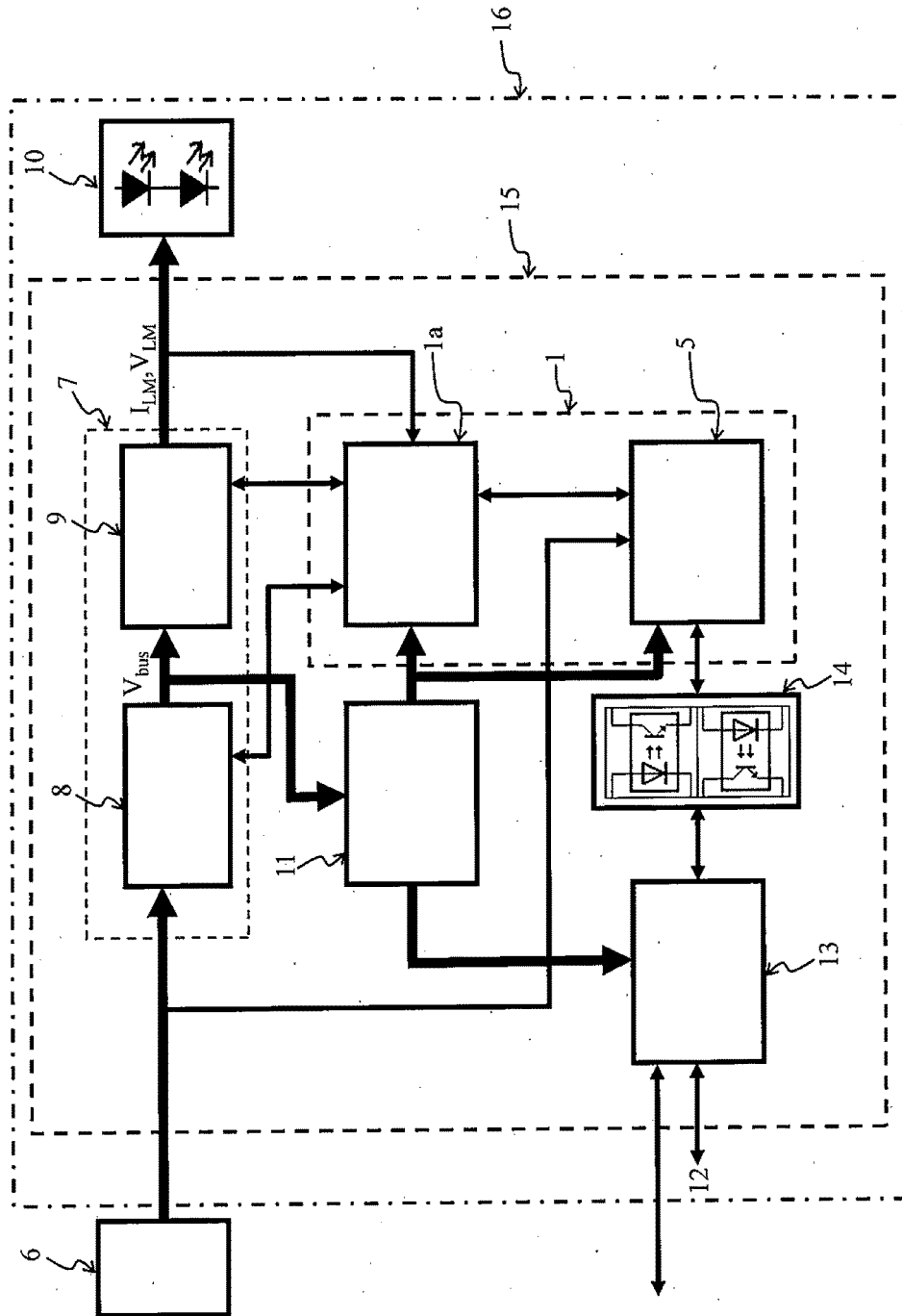


Figure 7



EUROPEAN SEARCH REPORT

Application Number

EP 22 15 7168

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EPO FORM 1503 03.82 (P04C01)

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	DE 10 2015 216584 A1 (TRIDONIC GMBH & CO KG [AT]) 2 March 2017 (2017-03-02) * [0004], [0005], [0027]- [0037], [0051]; figure 1 *	1-19	INV. H05B45/59 H05B47/20
Y	US 10 362 652 B1 (XIONG WEI [US] ET AL) 23 July 2019 (2019-07-23) * Figs. 1-2 and corresponding description parts *	1-19	
Y	US 2019/045600 A1 (ZENTENO LEOBARDO STEPHEN LINCOLN STRANGE [MX] ET AL) 7 February 2019 (2019-02-07) * paragraph [0032] - paragraph [0059]; figures 2-5 *	1-19	
			TECHNICAL FIELDS SEARCHED (IPC)
			H05B
The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 2 August 2022	Examiner Garavini, Elisa
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	

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ON EUROPEAN PATENT APPLICATION NO.**

EP 22 15 7168

5

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
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02-08-2022

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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
DE 102015216584 A1	02-03-2017	AT 16862 U1	15-11-2020
		DE 102015216584 A1	02-03-2017

US 10362652 B1	23-07-2019	NONE	

US 2019045600 A1	07-02-2019	NONE	

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EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82