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(54) A SWITCHED CONVERTER

(57) The invention relates to a switched converter, supplied with a DC voltage originating from an AC voltage, preferably mains voltage. The switched converter comprises output terminals for supplying an LED load, a feed-back loop controller configured to generate an output signal setting a switching frequency of at least one switch of the converter for controlling a load current on a nominal value, based on a signal indicating the load current and supplied to the feedback loop controller and a feed-forward control, FFC, block, wherein a response time of the FFC block is faster than a response time of the feed-back loop controller. The FFC block is configured to analyze in time increments said load current sensing signal and/or the DC signal as to a ripple present in said signals and to add a ripple compensation signal to said output signal of the feed-back loop controller.

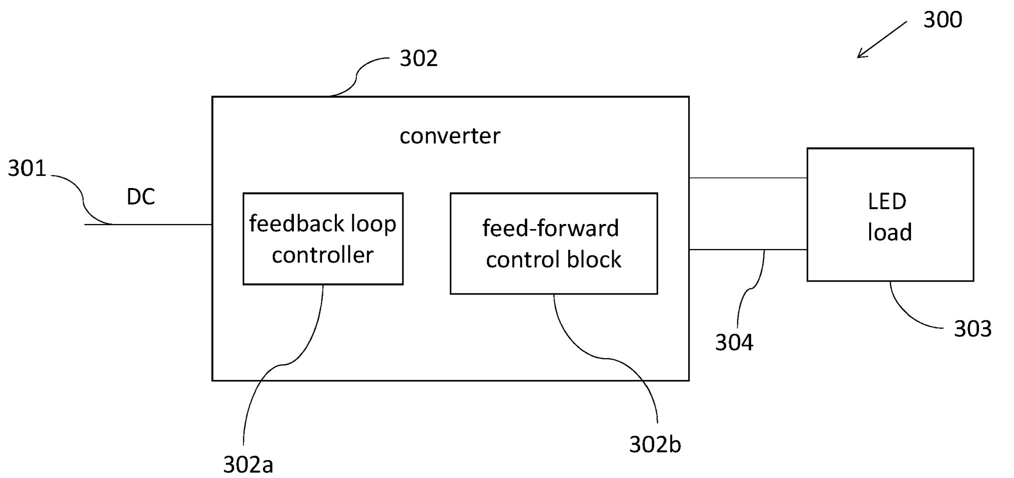

Fig. 3

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Description

TECHNICAL FIELD OF THE INVENTION

[0001] The invention relates to a switched converter which supplies an LED load. The invention further relates to an LED lighting module comprising such switched converter.

BACKGROUND OF THE INVENTION

[0002] The invention, generally, relates to the output current (LED current) feedback control in a switched converter, such as, for example, an LLC converter.

[0003] It is known how to directly or indirectly sense the LED current, compare it to a nominal value for the LED current, feed any deviation (error signal) to a controller (such as for example a PI controller) and, then, set the frequency of the switched converter (for example the switch-on time periods of LLC switchers) in accordance with the output signal of the controller in order to bring the actual LED current as close as possible to the nominal value thereof.

[0004] However, thereby, different scenarios may occur in which a ripple is produced in the output current (LED current).

[0005] One example is the 100 Hz ripple in the DC supply voltage or, for example, 400 VDC of the switched converter. This 100 Hz ripple should not be present in the output current.

[0006] Another example is given by the fact that the converter may also be used for a power supply for other gear, such as, for example, by acting as a DALI bus power supply. If this other gear supplied by the converter draws power in a certain frequency, this may lead to a ripple in the output current not fully compensated by the PI controller feedback loop.

[0007] A topology of LED gears which may be used in the invention is shown in Fig. 1. The mains voltage is rectified (not shown) and then filtered by the block electromagnetic interference (EMI) filter. Then, a boost converter (block boost PFC) is used for power factor correction and to produce a DC bus voltage (pV_bus) of about 400 V. This bus voltage is the input voltage of a half bridge LLC converter (block HB-LLC) which either provides the galvanically isolated input voltage for a third DC/DC block (e.g. a buck converter) or directly provides an output voltage / current to drive LED loads.

[0008] The DC bus voltage may be used to produce a low voltage power of e.g. 12V for a first control circuitry (e.g. ASIC). The ASIC may communicate with a second control circuitry (e.g. a microcontroller). The Microcontroller may be in charge of a communication interface (e.g. DALI, via an optocoupler). The microcontroller may have a further interface e.g. for inputting nominal values for the output current.

The first control circuitry may be supplied with a signal ILED representing the current on the secondary side of the galvanic isolation. The first control circuitry may control the switching of the switched converter via a signal HB-CTRL.

[0009] Due to design limitations, the DC bus voltage pV_bus is usually subject to the 100 Hz ripple. If the half bridge LLC circuit is operated at a constant frequency, which is not the case, the full ripple will be present in the LED current and, therefore, in the light. As the half bridge frequency is set by a controller that controls the average LED current, part of the 100 Hz ripple is suppressed by the controller.

[0010] Nevertheless, the rejection of the 100 Hz ripple is not ideal, because the controller is optimized for slower transients but not for 100 Hz.

[0011] In general, the output current depends on the half bridge frequency, the component values of the LLC converter (magnetizing inductance, resonance inductance, resonance capacitance), the LED voltage, the bus voltage, etc.... So, if optimal feed forward gain values are determined with one gear (or actually one gain per LED voltage), these values are not optimal with another gear.

[0012] Thus, it is an objective to provide for an improved switched converter with reduced output ripple.

SUMMARY OF THE INVENTION

[0013] The object of the present invention is achieved by the solution provided in the enclosed independent claims. Advantageous implementations of the present invention are further defined in the dependent claims.

[0014] According to a first aspect, the invention relates to a switched converter, supplied with a DC voltage originating from an AC voltage, preferably mains voltage. The switched converter comprises output terminals for supplying a LED load, a feed-back loop controller configured to generate an output signal setting a switching frequency of at least one switch of the converter for controlling a load current on a nominal value, based on a signal indicating the load current and supplied to the feed-back loop controller and a feed-forward control, FFC, block, wherein a response time of the FFC block is faster than a response time of the feed-back loop controller. The FFC block is configured to analyze in time increments said load current sensing signal and/or the DC signal as to a ripple present in said signals and to add a ripple compensation signal to said output signal of the feed-back loop controller.

[0015] Therefore, the controller may be optimized for slower transients and a FFC is added to the controller output in order to reject the 100 Hz ripple. Feed forward means that, based on the actual difference between the nominal or average bus voltage and the currently measured bus voltage, the half bridge frequency is either increased or decreased in order to compensate this deviation of the HB-LLC input voltage (pV_bus) .

[0016] In order for this deviation to be compensated (optimal rejection of the 100 Hz ripple) ideally, a feed forward gain should be determined. This gain specifies how much the half bridge frequency is increased or decreased in case the bus voltage differs by 1 V. It is given by the following equation, where ΔT_hb is the change of half bridge period necessary to compensate a change in the bus voltage ΔV_bus:

$$gain\_fefo = \frac{\Delta T\_hb}{\Delta V\ bus}$$

[0017] This gain can be determined during the design of the LED gear. However, due to the non-linear characteristics of the HB-LLC circuit, one gain value does not fit for all working points in which the HB-LLC circuit operates. For example, different gain values are required for different output voltages (LED voltages) because the characteristic of the HB-LLC circuit is steeper (steeper V_out to half bridge frequency relationship implies that only a low change of half bridge frequency is required to see an effect in the LED current) at high LED voltages and it is flatter (flatter V_out to half bridge frequency relationship implies that a higher change of half bridge frequency is required to see an effect in the LED current) at low LED voltages. Fig. 2 visualizes this behavior. It can be seen that at high output voltages, such as 300V the curve is very steep, whereas at low output voltages, such as 120 V, it is very flat.

[0018] This means that finding the correct feed forward gain for all working points is difficult and cannot be optimally set during the gear design, because the HB-LLC characteristics is also influenced by factors such as component tolerances.

[0019] In general, the output current depends on the half bridge frequency, the component values of the LLC converter (magnetizing inductance, resonance inductance, resonance capacitance), the LED voltage, the bus voltage, etc.... So, if optimal feed forward gain values are determined with one gear (or actually one gain per LED voltage), these values are not optimal with another gear.

[0020] According to an implementation form of the first aspect, the switched converter further comprises a sensing unit configured to directly or indirectly detect the load current and to forward the load current sensing signal based on the detected load current to the FFC block.

[0021] According to an implementation form of the first aspect, the FFC block is configured to evaluate an actual ripple value in the load current and to adjust the compensation signal at least partially on the basis of the actual ripple value.

[0022] According to an implementation form of the first aspect, the FFC block is further configured to adjust a gain of the FFC block on the basis of the actual ripple value.

[0023] According to an implementation form of the first aspect, the FFC block further comprises a self-learning, in particular artificial intelligence, block, which is configured to further adjust the compensation signal based on a learned algorithm taking into account at least one operation condition of the converter, in particular a value of a bus voltage, a temperature and/or a load characteristic.

[0024] According to an implementation form of the first aspect, the FFC block is configured to measure in discrete time periods a mains period and to adjust the compensation signal on the basis of the mains period.

[0025] According to an implementation form of the first aspect, the converter comprises a microcontroller, wherein the microcontroller comprises the FFC block, wherein the microcontroller is further configured to measure a frequency of the mains and to generate the compensation signal based on said frequency.

[0026] According to an implementation form of the first aspect, the switched converter is supplied with a DC bus voltage, wherein the FFC block is configured to receive a nominal or average value of the DC bus voltage and an actual value of the DC bus voltage, wherein the FFC block is configured to set the compensation signal based on the nominal or average value of the DC bus voltage and on the actual value of the DC bus voltage.

[0027] According to an implementation form of the first aspect, the switched converter is an LLC converter.

[0028] According to a second aspect, the invention relates to a LED lighting module having at least one converter according to any of the preceding claims and at least one LED load.

[0029] According to a third aspect, the invention relates to a method for supplying a LED load, comprising: generating an output signal setting a switching frequency of at least one switch of a converter for controlling a load current on a nominal value, based on a signal indicating a load current and supplied to a feedback loop controller, and analyzing in time increments of said load current sensing signal and/or a DC signal as to a ripple present in said signals and to add a ripple compensation signal to said output signal of the feedback loop controller.

[0030] According to an implementation of the third aspect, the method further comprises directly or indirectly detecting the load current, and forwarding the load current sensing signal based on the detected load current to the FFC block.

BRIEF DESCRIPTION OF THE DRAWINGS

[0031] The invention will be explained in the following together with the figures.

Fig. 1 shows a LED gear topology consisting of a boost converter and half bridge LLC converter;

Fig. 2 shows HB-LLC characteristics which depend on the LED voltage according to prior art;

Fig. 3 shows a switched converter according to an embodiment;

Fig. 4 shows a switched converter according to an embodiment;

Fig. 5 shows a switched converter according to an embodiment;

Fig. 6 shows LED current waveforms with different feed forward gains according to an embodiment;

Fig. 7 shows an HB-LLC circuit in a switched converter according to an embodiment; and

Fig. 8 shows a method for supplying a LED load according to an embodiment.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0032] Aspects of the present invention are described herein in the context of a switched converter for supplying LEDs.

[0033] The present invention is described more fully hereinafter with reference to the accompanying drawings, in which various aspects of the present invention are shown. This invention however may be embodied in many different forms and should not be construed as limited to the various aspects of the present invention presented through this disclosure. Rather, these aspects are provided so that this disclosure will be thorough and complete, and will fully convey the scope of the present invention to those skilled in the art. The various aspects of the present invention illustrated in the drawings may not be drawn to scale. Rather, the dimensions of the various features may be expanded or reduced for clarity. In addition, some of the drawings may be simplified for clarity. Thus, the drawings may not depict all of the components of a given apparatus.

[0034] Various aspects of a switched converter will be presented. However, as those skilled in the art will readily appreciate, these aspects may be extended to aspects of switched converters without departing from the invention.

[0035] It is further understood that the aspect of the present invention might contain integrated circuits that are readily manufacturable using conventional semiconductor technologies, such as complementary metal-oxide semiconductor technology, short "CMOS". In addition, the aspects of the present invention may be implemented with other manufacturing processes for making optical as well as electrical devices. Reference will now be made in detail to implementations of the exemplary aspects as illustrated in the accompanying drawings. The same references signs will be used throughout the drawings and the following detailed descriptions to refer to the same or like parts.

[0036] Now referring to Fig. 3, a system 300 comprising a switched converter 302 according to an embodiment is shown.

[0037] The switched converter 302, supplied with a DC voltage 301 originating from an AC voltage, preferably mains voltage, comprises:

- output terminals 304 for supplying a LED load 303;
- a feedback loop controller 302a configured to generate an output signal setting a switching frequency of at least one switch of the converter 302 for controlling a load current on a nominal value, based on a signal indicating the load current and supplied to the feedback loop controller 302a;
- a feed-forward control, FFC, block 302b, wherein a response time of the FFC block 302b is faster than a response time of the feed-back loop controller 302a.

[0038] Moreover, the FFC block 302b is configured to analyze in time increments of said load current sensing signal and/or the DC signal 301 as to a ripple present in said signals and to add a ripple compensation signal to said output signal of the feed-back loop controller 302a.

[0039] According to an embodiment, the feed forward gain can be determined online (so during runtime of the gear) automatically. In this case, the optimal feed forward gain value is found by the gear autonomously.

[0040] Fig. 4 shows the system 300 comprising the switched converter 302 according to an embodiment.

[0041] In this embodiment, the converter 302 comprises a mains frequency detection block 401, a microcontroller 400 and an LED driver 404. The microcontroller 400 comprises a frequency analyzer and anti-phase signal generator block 402, a logic block or FFC block 302b, the controller 302a, an LED current demand block 403 and a signal combination block 405.

[0042] In an embodiment, a smart software algorithm allows the LED current controller 302a to cancel the low frequency ripple created by the first stage of the driver.

[0043] In an embodiment the driver is a flyback driver.

[0044] The first stage of the driver would "mirror" the mains frequency on to the secondary side and create a 100 Hz - 120 Hz low frequency, LF, ripple on the bus. Then, the LED current source supplied from this rail would transfer this 100 Hz - 120 Hz ripple on to the LED current.

[0045] Low cost LED drivers can be configured to use only simple filters to limit the amount of ripple present on the V_bus, hence limiting the LED current ripple. In order to reduce the LF ripple, the controller 302a based on the microcontroller 400 can superimpose the generated sinusoidal signal to counteract the LF ripple.

[0046] However, in an embodiment, the LF ripple is monitored continuously, which requires real time system, with minimal delay time between taking samples and adjusting the controller 302a.

[0047] In an embodiment, the logic block 302b includes an algorithm comprising the following instructions:

- measure the low frequency (LF) for certain short time;

- determine which is the frequency of the LF ripple on the DC bus;
- lock in to the measured frequency;
- generate a sinusoidal signal with anti-phase to the LF ripple on the DC bus;
- superimpose said signal to the controller target level, and actively adjust the gate signals to counteract the LF ripple in the LED current; and
- randomly check if the initially measured frequency is still within predetermined limits.

[0048] By doing so, the microcontroller 400 can reduce the LF ripple in the LED current, while doing all other tasks as designated.

[0049] The above solution is based on the assumption that mains frequency is stable and does not change. This assumption is correct for large AC system in which all generators are synchronized and mains frequency does not vary.

[0050] Therefore, the smart algorithm decides the frequency and amplitude of the ripple cancelling signal based on very few samples, and assumes that they are fixed throughout the operation of the driver. This limits the amount of hardware and software resources needed to actively cancel the LF ripple in the LED current

[0051] This has the advantage that a simple solution is provided for fixed output drivers, and emergency divers that utilize already existing system to improve light quality and reduce the LF LED ripple current.

[0052] Moreover, low limits of the LF ripple can be achieved without additional circuits and without large storage elements, i.e. electrolytic capacitors.

[0053] Fig. 5 shows a switched converter 302 according to an embodiment.

[0054] In this embodiment, the output current (LED current) is monitored, as explained in the following.

[0055] The average output current is measured anyway, because it is the required feedback signal for the feedback loop controller 302a, e.g. a HB-LLC control loop, only a measurement (tracking) of the output current peak value should be added.

[0056] The peak value can be found by a peak tracking block within the microcontroller 400, e.g. an ASIC. In case of an optimal feed forward gain, the difference between peak value and average value will be almost zero (in ideal case it is zero) . In case of a too high or too low feed forward gain, the difference between peak and average will be larger.

[0057] The feed forward control block 302b does not only receive the average (or nominal) bus voltage V_bus_avg and the currently measured bus voltage V_bus, but also information about the average and actual (or peak) LED current. Based on the current information the feed forward gain can be optimized (or controlled) until the difference between ILED_pk and ILED_avg is at a minimum.

[0058] In an embodiment the DC/DC switched converter 302 that is used to supply LED loads is a buck converter or flyback converter.

[0059] In an embodiment, the switched converter 302 only provides a fixed output voltage, which is then the input voltage for a further stage that then supplies the LED load. In this case, the feed forward gain is determined by comparison of the average output voltage and the peak output voltage.

[0060] Fig. 6 shows exemplary waveforms of the LED current with different feed forward gains.

[0061] In the upper plot a not optimal feed forward gain is utilized: if it is too low, the waveform will look like as shown in the upper panel, if it is too high, the ripple on the bus voltage will be over-compensated and the resulting ripple on the output current will be inverted.

[0062] In the lower plot, an almost optimal feed forward gain is utilized, it can be seen that the 100 Hz ripple almost vanishes.

[0063] In an embodiment, it is proposed to add to the PI controller 302a a feed forward control block 302b, which has a shorter (faster) response time than the response time of the PI controller 302a.

[0064] Generally, the feed forward control block 302b is supplied with the LED current sensing signal, and adds a compensation/correction value to the output signal of the feedback loop controller 302a, in order to reduce any ripple, which might occur in the output current, and not fully compensated by the relatively slow PI controller 302a.

[0065] According to an embodiment, the feed-forward control block 302b evaluates/measures any ripple in the LED current and adjusts its gain depending on the actual ripple value.

[0066] For example, if at the beginning of the compensation procedure or operation of the controller 302a there is a relatively high ripple on the output signal, the feed forward control may start with a low gain and increase it until the gain has an optimum value, in which the ripple is essentially compensated.

[0067] However, as soon as the gain has reached an optimal value, in which the ripple is essentially compensated, it shall not be increased further, as this may lead to instabilities in the controller 302a and even to the artificial production of ripple in the output current.

[0068] Moreover, the feed-forward control 302b may comprise a self-learning (artificial intelligence) block, which learns as how to adjust the gain depending on the operation conditions (value of the bus voltage, temperature, load characteristics, etc.).

[0069] The feed forward control block 302b may be supplied with a nominal value for the DC bus voltage as well as an actual value of the bus voltage, wherein these supplied signals are taken into account for adjusting the gain of the feed forward control block.

[0070] However, in an embodiment, one of the signals supplied to the feed forward control block may not be the nominal value of the bus voltage (which may vary from device to device), but the average value of the measured bus voltage.

[0071] In an embodiment, the mains-induced low frequency current ripple is compensated by a "smart algorithm", measuring in discrete time periods the mains period and, then, generating a compensation signal to reduce the forecast ripple between the measurement of the mains frequency and the next frequency measuring step.

[0072] Thus, in general, an adaptive, self-learning and also feed forward approach is used in the sense that, dependent on measurements, a compensation is performed until the next measurement is carried out.

[0073] In an embodiment, the smart algorithm produces a compensation signal, which is super-imposed in a feed forward manner onto the output signal of the feedback controlled loop.

[0074] Preferably, the microcontroller 400 is used for measuring the frequency of the mains and to generate the compensation signal. The computation effort and the resources required are relatively low, as the measurement of the mains frequency is only done in discrete steps and the compensation signal is then used for a given time period.

[0075] Therefore, advantageously, the microcontroller 400 already used for other purposes (communication, processing of dimming signals, etc.) can also be used for this task.

[0076] One application for this invention is the area of so-called maintained LED drivers, which are drivers which may charge a battery from mains and then in an emergency case operate emergency lighting means of the battery, and at the same time, drive other or the same lighting means of the mains supply.

[0077] Fig. 7 shows an HB-LLC circuit 501 according to an embodiment.

[0078] In this embodiment, only the power components are shown, and no sensing components.

[0079] The HB-LLC circuit comprises two switches M40 and M41, moreover the capacitor C51 is connected to a primary side winding L51d, which is coupled to two windings L51a and L51b.

[0080] Moreover, on the secondary side two diodes are provided D50a and D50b as well as a capacitor C52, which is connected to the LED load.

[0081] Fig. 8 shows a method 800 for supplying a LED load 303 according to an embodiment.

[0082] The method 800 comprises the following steps:

- generating 801 an output signal setting a switching frequency of at least one switch of a converter 302 for controlling a load current on a nominal value, based on a signal indicating a load current and supplied to a feedback loop controller 302a; and

- analyzing 802 in time increments of said load current sensing signal and/or a DC signal as to a ripple present in said signals and to add a ripple compensation signal to said output signal of the feedback loop controller 302a.

[0083] All features of all embodiments described, shown and/or claimed herein can be combined with each other.

[0084] While various embodiments of the present invention have been described above, it should be understood that they have been presented by way of example only and not limitation. Numerous changes to the disclosed embodiments can be made in accordance with the disclosure herein without departing from the spirit of scope of the invention. Thus, the breadth and scope of the present invention should not be limited by any of the above-described embodiments. Rather, the scope of the invention should be defined in accordance with the following claims and their equivalence.

[0085] Although the invention has been illustrated and described with respect to one or more implementations, equivalent alternations and modifications will occur to those skilled in the art upon the reading of the understanding of the specification and the annexed drawings. In addition, while a particular feature of the invention may have been disclosed with respect to only of the several implementations, such features may be combined with one or more other features of the other implementations as may be desired and advantage for any given or particular application.

Claims

1. A switched converter (302), supplied with a DC voltage (301) originating from an AC voltage, preferably mains voltage, comprising:

   - output terminals (304) for supplying a LED load (303);
   - a feedback loop controller (302a) configured to generate an output signal setting a switching frequency of at least one switch of the converter (302) for controlling a load current on a nominal value, based on a signal indicating the load current and supplied to the feedback loop controller (302a);
   - a feed-forward control, FFC, block (302b), wherein a response time of the FFC block (302b) is faster than a response time of the feed-back loop controller (302a), and wherein

     - the FFC block (302b) is configured to analyse in time increments of said load current sensing signal and/or the DC signal (301) as to a ripple present in said signals and to add a ripple compensation signal to said output signal of the feed-back loop controller (302a) .

2. The switched converter (302) of claim 1, wherein the switched converter (302) further comprises a sensing unit (502) configured to directly or indirectly detect the load current and to forward the load current sensing signal based on the detected load current to the FFC block (302b).

3. The switched converter (302) of claim 1 or 2, wherein the FFC block (302b) is configured to evaluate an actual ripple value in the load current and to adjust the compensation signal at least partially on the basis of the actual ripple value.

4. The switched converter (302) of claim 3, wherein the FFC block (302b) is further configured to adjust a gain of the FFC block (302b) on the basis of the actual ripple value.

5. The switched converter (302) according to any one of the preceding claims, wherein the FFC block (302b) further comprises a self-learning, in particular artificial intelligence, block, which is configured to further adjust the compensation signal based on a learned algorithm taking into account at least one operation condition of the converter, in particular a value of a bus voltage, a temperature and/or a load characteristic.

6. The switched converter (302) of any one of the preceding claims, wherein the FFC block (302b) is configured to measure in discrete time periods a mains period and to adjust the compensation signal on the basis of the mains period.

7. The switched converter (302) of claim 6, wherein the converter (302) comprises a microcontroller (400), wherein the microcontroller (400) comprises the FFC block (302b), wherein the microcontroller (400) is further configured to measure a frequency of the mains and to generate the compensation signal based on said frequency.

8. The switched converter (302) according to any one of the preceding claims, wherein the switched converter (302) is supplied with a DC bus voltage, wherein the FFC block (302b) is configured to receive a nominal or average value of the DC bus voltage and an actual value of the DC bus voltage, wherein the FFC block (302b) is configured to set the compensation signal based on the nominal or average value of the DC bus voltage and on the actual value of the DC bus voltage.

9. The switched converter (302) according to any one of the preceding claims, wherein the switched converter (302) is an LLC converter.

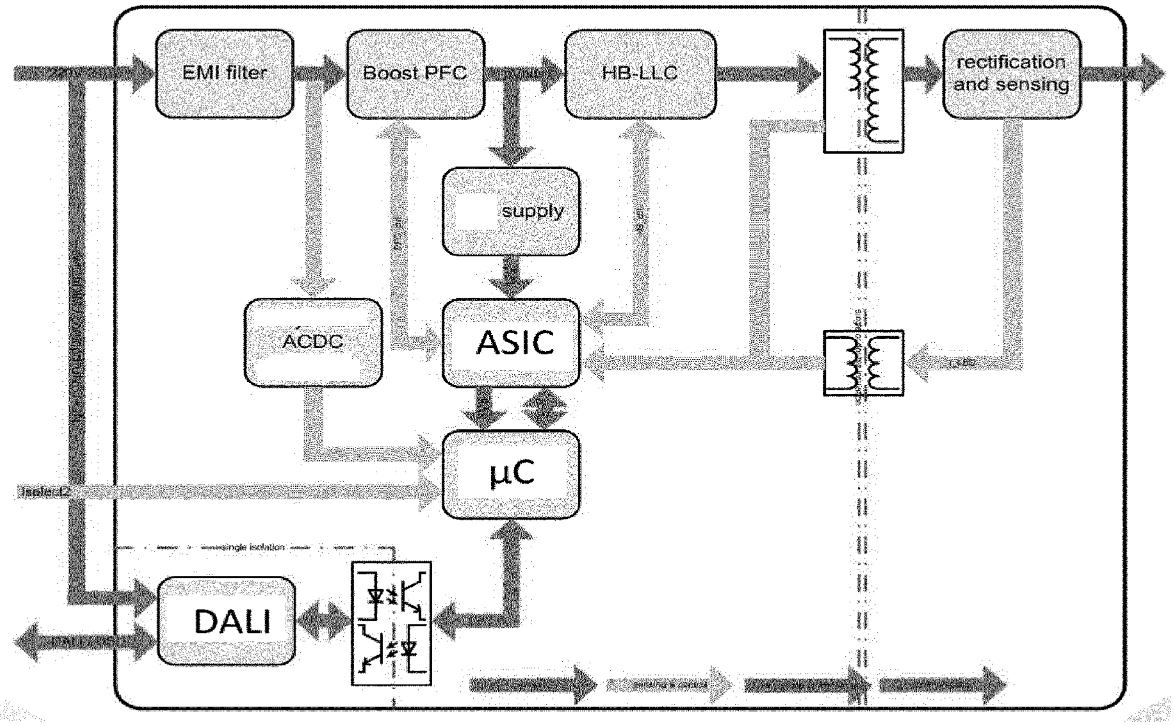
10. A LED lighting module having at least one converter according to any of the preceding claims and at least one LED load.

11. Method (800) for supplying a LED load (300), comprising:

- generating (801) an output signal setting a switching frequency of at least one switch of a converter (302) for controlling a load current on a nominal value, based on a signal indicating a load current and supplied to a feedback loop controller (302a); and
- analysing (802) in time increments of said load current sensing signal and/or a DC signal as to a ripple present in said signals and to add a ripple compensation signal to said output signal of the feedback loop controller (302a).

12. Method (800) according to claim 11, further comprising:

- directly or indirectly detecting the load current; and
- forwarding the load current sensing signal based on the detected load current to a FFC block (302b).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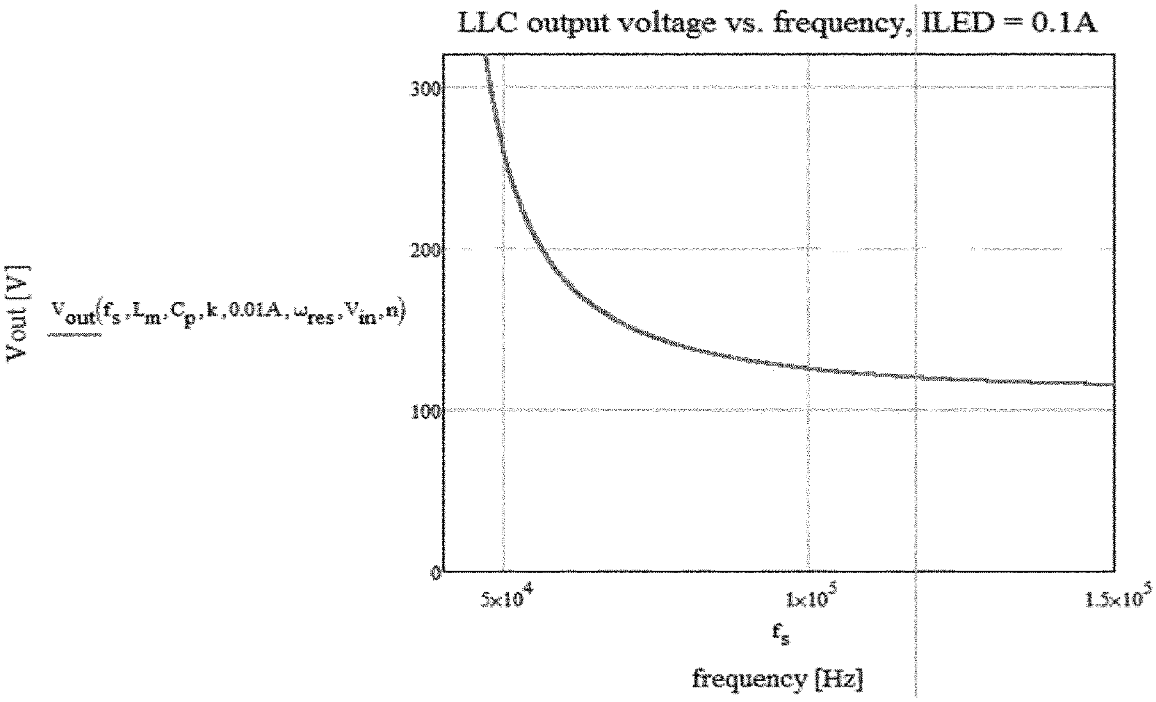
Boost PFC
HB-LLC
rectification
and sensing
supply
ACDC
ASIC
μC
Iselect2
DALI
single isolation

Fig. 1


LLC output voltage vs. frequency, ILED = 0.1A
300
200
100
0
Vout [V]
Vout(fs, Lm, Cp, k, 0.01A, ωres, Vin, n)
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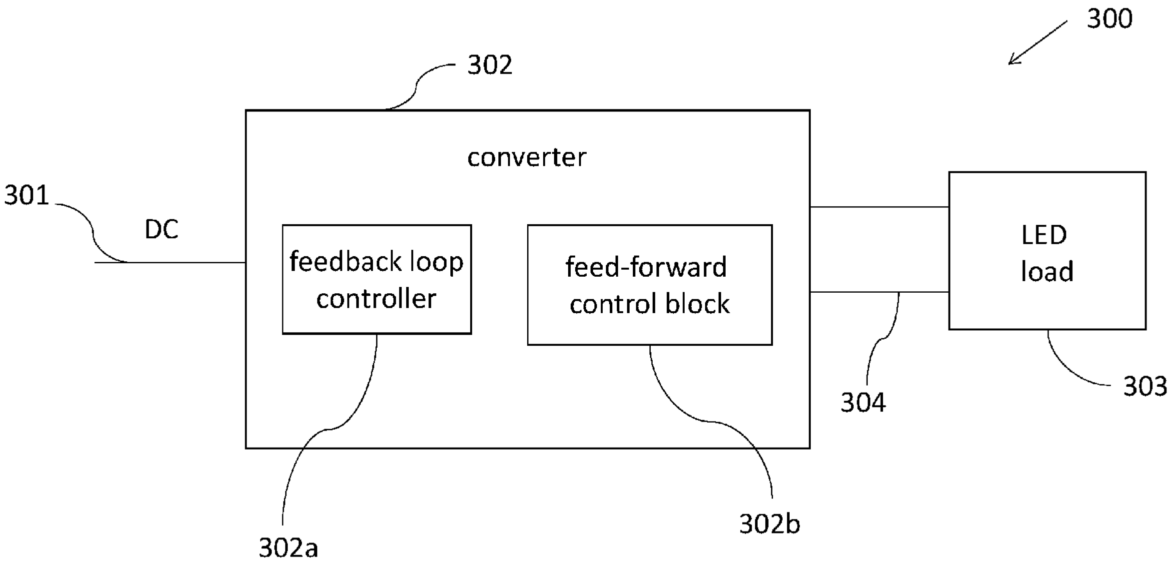
1×10^5
1.5×10^5
fs
frequency [Hz]

Fig. 2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converter
301
DC
feedback loop controller
feed-forward control block
LED load
304
303
302a
302b

Fig. 3

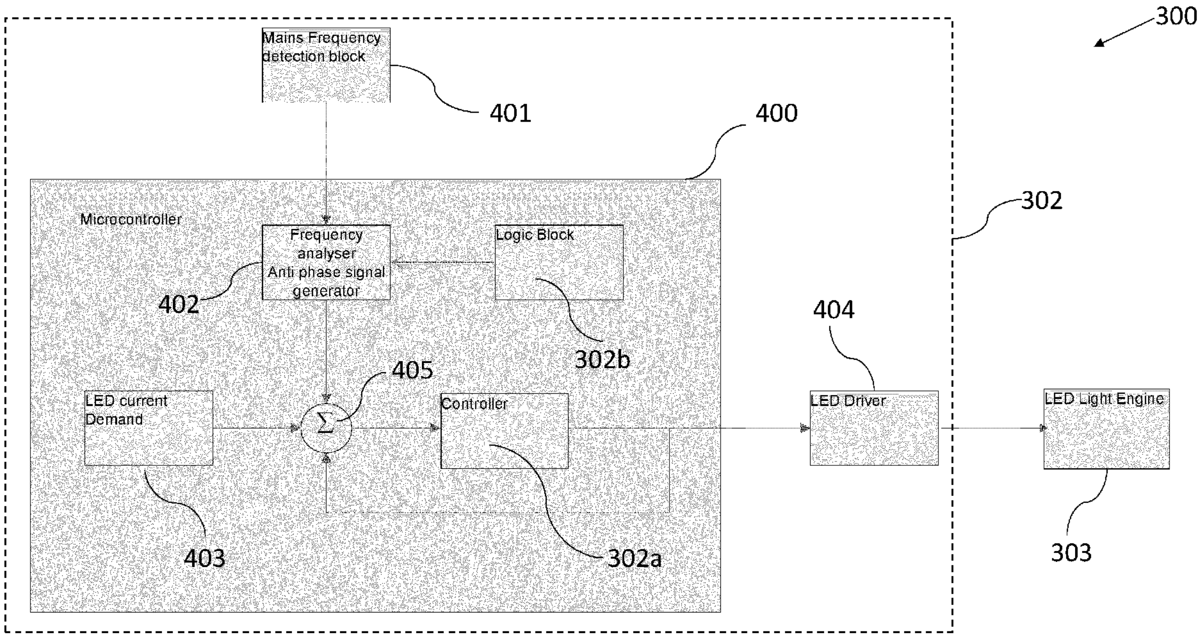
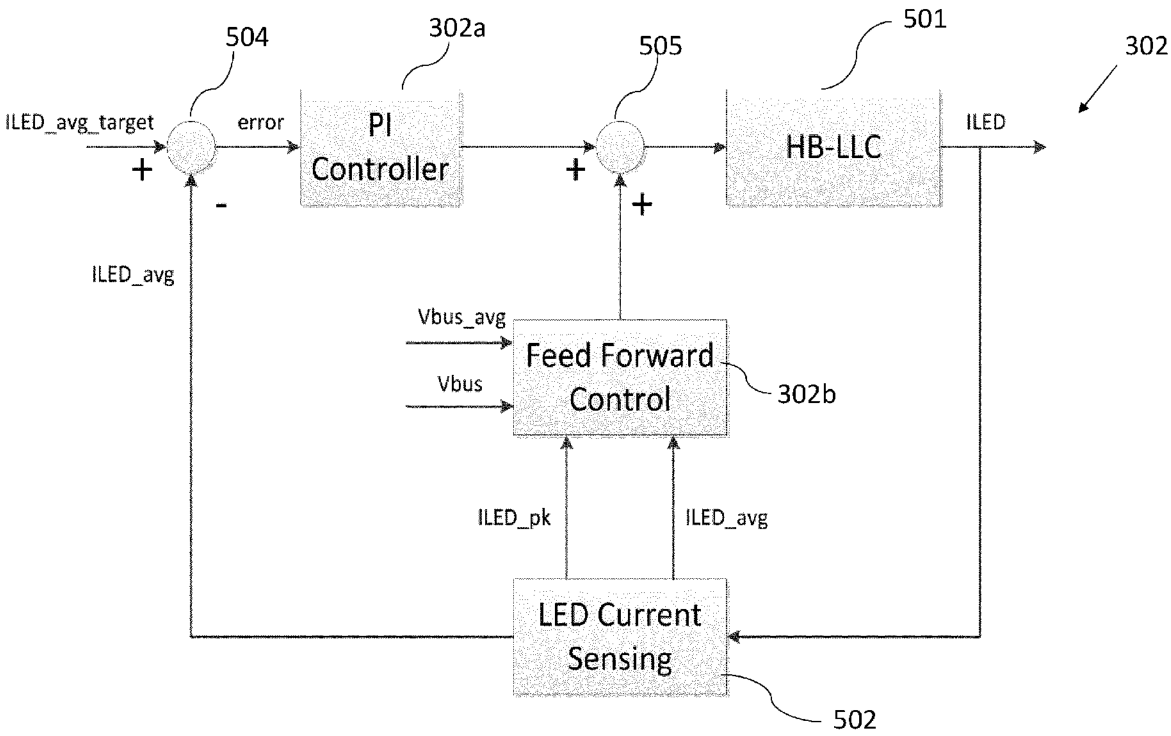

300
Mains Frequency detection block
401
400
Microcontroller
302
Frequency analyser Anti phase signal generator
Logic Block
402
302b
404
405
LED current Demand
Σ
Controller
LED Driver
LED Light Engine
403
302a
303

Fig. 4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302a
505
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302
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+
+
HB-LLC
ILED
+
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Vbus_avg
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Vbus
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ILED_avg
LED Current Sensing
502

Fig. 5

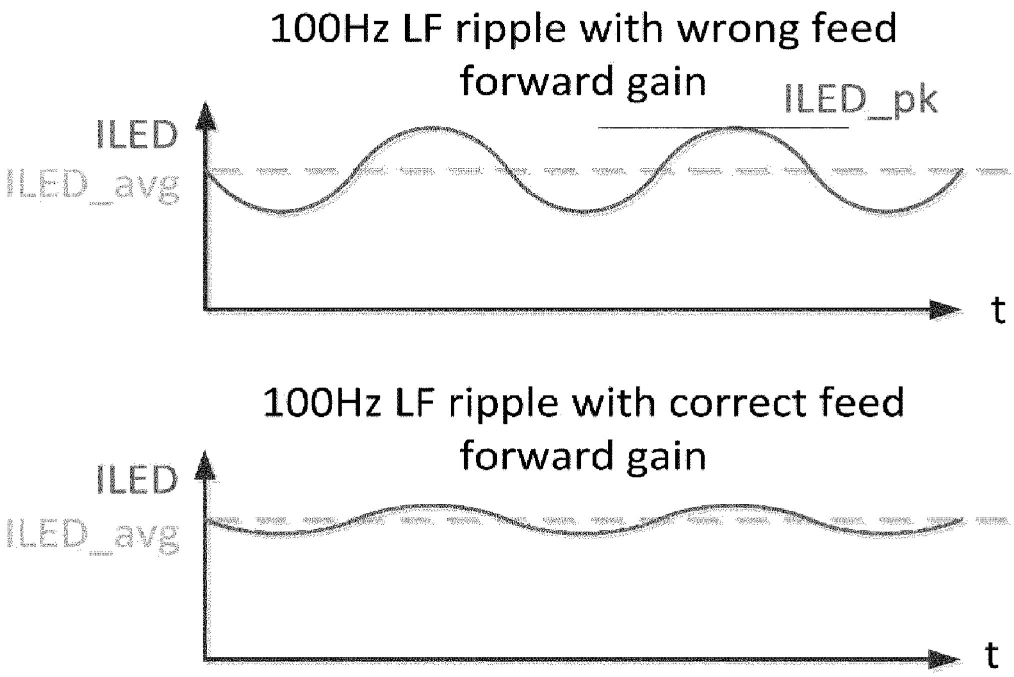
100Hz LF ripple with wrong feed forward gain
ILED_pk
ILED
ILED_avg
t
100Hz LF ripple with correct feed forward gain
ILED
ILED_avg
t

Fig. 6

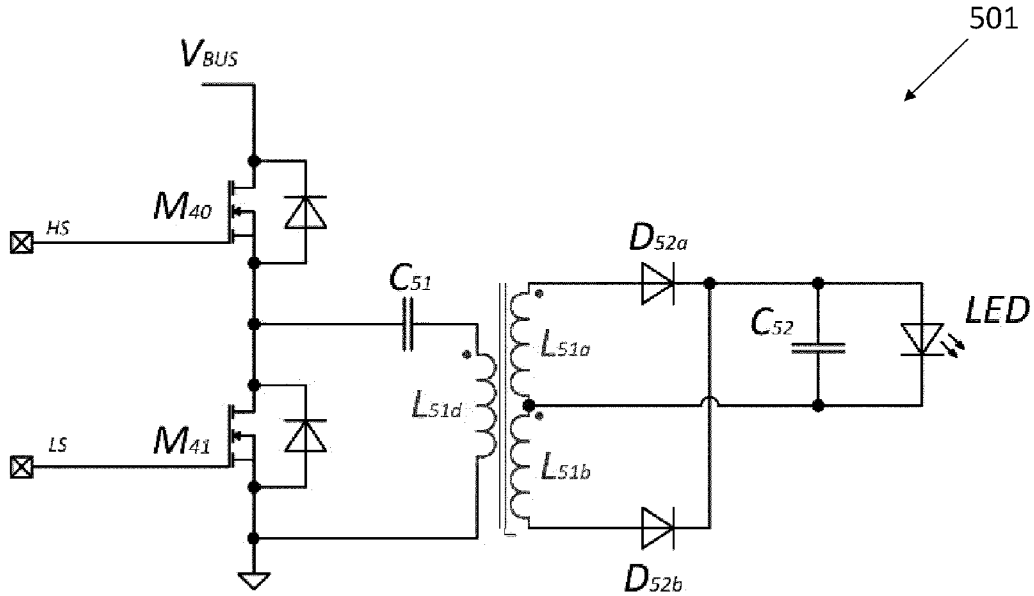

Fig. 7

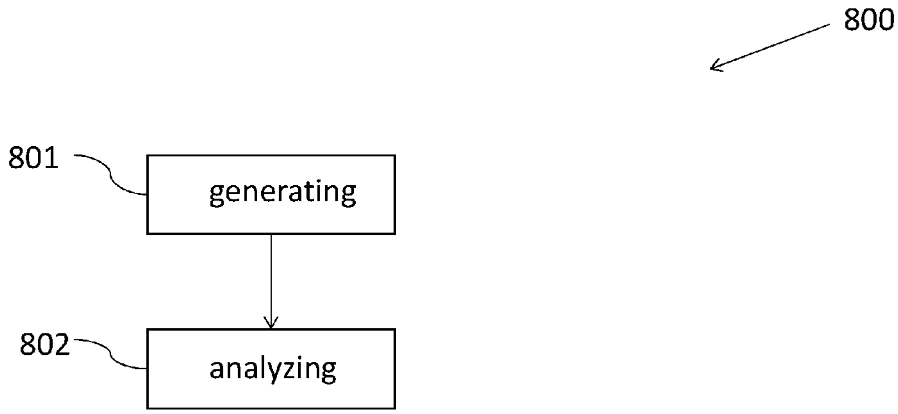

Fig. 8

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EUROPEAN SEARCH REPORT

Application Number
EP 20 17 3164

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H05B
H03K
H02M

The present search report has been drawn up for all claims

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Place of search	Date of completion of the search	Examiner
Munich	13 October 2020	Hernandez Serna, J

CATEGORY OF CITED DOCUMENTS

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