(19) Europäisches Patentamt / European Patent Office / Office européen des brevets

(11) EP 3 065 507 A1

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
07.09.2016 Bulletin 2016/36

(51) Int Cl.:
H05B 33/08 *(2006.01)*

(21) Application number: **15157299.7**

(22) Date of filing: **03.03.2015**

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME
Designated Validation States:
MA

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(54) **Method and apparatus for controlling a primary stage of a light driver device**

(57) There are provided a driver device for light-emitting means, as well as a method for operating a driver device for light-emitting means. The method comprises:
- producing a bus voltage on a galvanically isolated secondary side of the driver device,
- utilizing feedback from the secondary side to a primary side of the driver device to make a primary side controller decrease said bus voltage during standby mode, and
- implementing, through actions of said primary side controller, at least one further standby mode function on the primary side as a response to a decreasing value of said bus voltage.

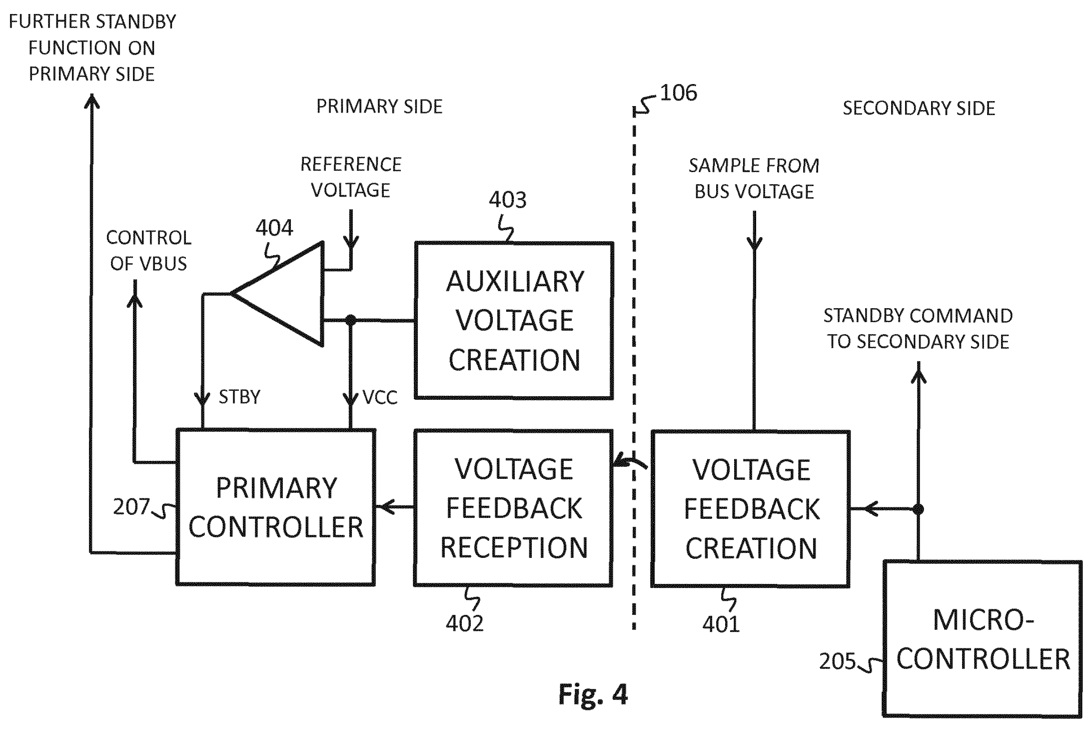

Fig. 4

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Description

FIELD OF THE INVENTION

[0001] The invention concerns the field of controlling the operation of a primary stage in a driver device that drives light-emitting means. Especially the invention concerns a method and a device that enable saving power, avoiding unnecessarily complicated operation and circuitry, and increasing reliability in a driver device that can be temporarily put into a standby mode.

BACKGROUND

[0002] A driver device of light-emitting means has multiple functions. It must transform the available grid voltage (for example: 230 volts AC at 50 Hz) to the voltage - and frequency, if the light-emitting means work on AC - suitable for the light-emitting means, and regulate the voltage and current led to the light-emitting means. It must implement the control operations needed for lighting that should be dimmable and/or otherwise controllable. In many cases it must isolate, in galvanic sense, the output connected to the light-emitting means from the input side connected to the grid voltage. It must also take care that any possible highfrequency oscillations, or other kind of interference generated internally in the driver device and/or the light-emitting means, do not propagate backwards to the supply voltage grid. Additionally it should optimize all consumption of electric energy.

[0003] Fig. 1 illustrates schematically an example of a driver device for light-emitting means, particularly light-emitting diodes or just LEDs for short. An input section 101 is adapted to be coupled to a mains grid, for example 230 volts AC at 50 Hz. The input section 101 typically contains passive filtering components as well as a rectifier bridge, and is adapted to produce an internal DC voltage between the lines marked VDC and GND. This internal DC voltage goes into a DC-DC converter section 102, which typically comprises one or two switched-mode power supply stages. In a two-stage approach the first stage (not separately shown) is a PFC (power factor correction) stage, and the second stage (not separately shown) is for example a flyback converter adapted to produce another internal DC voltage between the lines marked VBUS and 0V. The last-mentioned voltage, which is commonly called the bus voltage, goes into one or more output stages, of which section 103 is shown in fig. 1. Its output nodes are marked LED+ and LED- to signify that a LED chain can be coupled therebetween.

[0004] The driver device of fig. 1 is controllable, which means that it comprises a control interface section 104 adapted to be coupled to a control bus. In this example a DALI (Digital Addressable Lighting Interface) is shown as an example. The control interface section 104 is coupled to a secondary side controller 105 that receives control commands from the control bus and controls the operation of the driver device accordingly.

[0005] The driver device is divided into a primary side and a secondary side along a galvanic isolation line 106. On the secondary side are the output stage(s) 103, the secondary side controller 105 and the control interface section 104, as well as the secondary winding and related components (not separately shown) of an isolation transformer that constitutes a part of the DC-DC converter section 102. The couplings between the control interface section 104 and the secondary side controller 105 typically involve galvanic isolation, so it is also possible to count the control interface section 104 as belonging to the primary side of the driver device.

[0006] In order to properly control the operation of the DC-DC converter section 102 there is a primary controller 107 that belongs to the primary side of the driver device. Each of the controllers 105 and 107 may receive various measured values that are all schematically represented with a single line marked MON respectively. They may also send various controlling signals that are all schematically represented with a single line marked CTRL respectively.

[0007] When the driver device is commanded into a standby state or sleep mode, it should shut down all but the most important functions that keep it "alive" waiting for further commands. Noting that the secondary side controller 105 gets its operating voltage originally from the mains grid through sections 101 and 102, it is understandable that some electric energy must continue to flow through these sections also in standby mode even if no such energy is directed to the outputs LED+ and LED-. However, the amount of required electric energy is so small that a large part of the functions that are normally active in section 102 can be shut down or at least turned to an energy-saving mode. This means that the secondary side controller 105 must somehow inform the primary side controller 107 about the standby mode.

[0008] A feedback coupling typically exists between the secondary side controller 105 and the primary side controller 107, for enabling the former to give feedback on e.g. the level of the bus voltage. In order to maintain the galvanic isolation, the feedback coupling must go through an optocoupler or corresponding isolating means. A prior art document US 2012/0313537 A1 (Gruber et al) suggests building a parallel feedback coupling for conveying a standby command. However, using a dedicated optocoupler for this purpose makes the circuit more complicated. Optocouplers are also notoriously prone to aging, which means that an optocoupler-based feedback coupling adds a possible point of failure and thus weakens reliability.

SUMMARY

[0009] It is an objective of the present invention to provide a method and devices for controlling the operation of a primary stage in a driver device that drives light-emitting means so that power is saved, unnecessarily complicated operation and circuitry is avoided, and reliability is increased.

[0010] The objectives of the invention are reached with a method and apparatus as defined by the respective independent claims.

[0011] According to an example embodiment, there is provided a driver device for light-emitting means, comprising:

- a primary side adapted to receive an input voltage,
- a secondary side adapted to produce an output voltage, the secondary side being galvanically isolated from the primary side,
- a power supply adapted to produce a bus voltage for the secondary side, with an isolation transformer of said power supply bridging the borderline between the primary and secondary sides,
- on the primary side a primary side controller adapted to control said power supply,
- on the secondary side a secondary side controller, and
- a feedback coupling from said secondary side to said primary side;
  wherein said secondary side controller is adapted to utilize said feedback coupling to make the primary side controller decrease said bus voltage during standby mode, and wherein said primary side controller is adapted to make said power supply implement at least one further standby mode function as a response to a decreasing value of said bus voltage.

[0012] According to another example embodiment, there is provided a method for operating a driver device for light-emitting means, comprising:

- producing a bus voltage on a galvanically isolated secondary side of the driver device,
- utilizing feedback from the secondary side to a primary side of the driver device to make a primary side controller decrease said bus voltage during standby mode, and
- implementing, through actions of said primary side controller, at least one further standby mode function on the primary side as a response to a decreasing value of said bus voltage.

[0013] The exemplifying embodiments of the invention presented in this patent application are not to be interpreted to pose limitations to the applicability of the appended claims. The verb "to comprise" and its derivatives are used in this patent application as an open limitation that does not exclude the existence of also unrecited features. The features described hereinafter are mutually freely combinable unless explicitly stated otherwise.

[0014] The novel features which are considered as characteristic of the invention are set forth in particular in the appended claims. The invention itself, however, both as to its construction and its method of operation, together with additional objects and advantages thereof, will be best understood from the following detailed description of specific embodiments when read in connection with the accompanying drawings.

BRIEF DESCRIPTION OF DRAWINGS

[0015]

Fig. 1	illustrates a driver device for light-emitting means,
fig. 2	illustrates a driver device for light-emitting means,
fig. 3	illustrates a driver device for light-emitting means,
fig. 4	illustrates schematically deriving a standby mode command from a decreasing auxiliary voltage,
fig. 5	illustrates an exemplary circuit for producing bus voltage feedback in a controllable manner,
fig. 6	illustrates parts of a driver device for light-emitting means,
fig. 7	illustrates schematically deriving an augmented switch current indicator value and using it as a transmitted power feedback value, and
fig. 8	illustrates parts of a driver device for light-emitting means.

DETAILED DESCRIPTION OF EMBODIMENTS OF THE INVENTION

[0016] Fig. 2 is a block diagram of a driver device for light-emitting means. The dashed borderline 106 illustrates the division of the driver device into a primary side, which is adapted to receive an input voltage (here 230 volts AC), and a secondary side, which is adapted to produce an output voltage across the nodes marked LED+ and LED-. The secondary side is galvanically isolated from the primary side. As in fig. 1, conceptually it is insignificant whether the control bus interface 104 is considered to belong to the primary side or to the secondary side.

[0017] The primary side comprises a power supply adapted to produce a bus voltage for the secondary side. The bus voltage appears between the nodes marked VBUS and 0V in fig. 2. The power supply is schematically shown to comprise the DC-DC converter block 202 as well as an isolation transformer 203 that bridges the borderline 106 between the primary and secondary sides. On the primary side a primary side controller 207 is adapted to control the power supply, and thus to control the production of the bus voltage. On the secondary side the driver device comprises a secondary side controller 205.

[0018] A feedback coupling exists from the secondary side to the primary side. The secondary side controller 205 is adapted to utilize the feedback coupling to the make the primary side controller 207 decrease the bus voltage during standby mode. A detailed example of how that works is found for example in the European patent application number EP15150633.4, which was filed on 9 January 2015 and which is not available to the public at the original filing date of this description, but is incorporated herein in its entirety by reference thereto.

[0019] Decreasing the bus voltage during standby mode is based on the observation that since electric energy is not needed for illuminating the lighting means during standby mode but only to keep the secondary side controller "alive", and since the operating voltage required by the secondary side controller is typically significantly smaller than the bus voltage needed to illuminate the lighting means, a lower bus voltage may help to reduce losses while still keeping the necessary control functions running during standby mode. The difference between the full and decreased bus voltage may be significant, like 10 - 50% of the full bus voltage or even more.

[0020] It is important to understand that the feedback signal that comes from the secondary side to the primary side and that causes the primary side controller to lower the bus voltage is not a standby command as such. A major function of the feedback coupling is typically to maintain an appropriate level of the bus voltage during normal operation. For that purpose the secondary side may comprise a bus voltage feedback circuit (not separately shown in fig. 2) adapted to utilize the feedback coupling to provide the primary side controller with a bus voltage feedback value. The way in which the feedback signal reflects the actual bus voltage is controllable, which is emphasized in fig. 2 by marking the feedback coupling as controllable feedback. By changing the way in which the feedback signal reflects the actual bus voltage during standby mode, the secondary side controller 205 essentially causes the primary side controller 207 to act as if bus voltage levels typical to normal operation would be grossly exceeded, so that as a consequence, the primary side controller makes the power supply lower the bus voltage.

[0021] The primary side controller 207 is additionally adapted to make the power supply implement at least one further standby mode function as a response to a decreasing value of the bus voltage. In a way, the primary side controller 207 - after having itself made the bus voltage decrease - notices a decrease in the bus voltage and interprets this decrease as a command to enter standby mode. In fig. 2 this is schematically shown with a measurement coupling from the primary side of the isolation transformer 203 to the primary side controller 207 at point 206. Since one of the aims of the described solution is to avoid excessive transfer of signals - and the consequent need for optoisolators - across the borderline 106 between the primary and secondary sides, it is advantageous if the primary side controller 207 can be made to notice the decrease in bus voltage solely with components on the primary side. Fig. 3 illustrates schematically one possible such approach. The driver device of fig. 3 comprises an auxiliary winding in the isolation transformer 203 for producing an auxiliary voltage to the primary side controller 207 at the point schematically illustrated as 306. The primary side controller 207 of fig. 3 is adapted to detect the decreasing value of the bus voltage indirectly through a decrease in said auxiliary voltage.

[0022] The bus voltage comes essentially from a secondary winding in the isolation transformer 203. Consequently, if the auxiliary winding has the same polarity as the secondary winding and the inductive couplings between the coils in the isolation transformer remain constant, the voltage induced in the auxiliary winding follows closely the voltage induced into the secondary winding, only scaled by the relative numbers of turns in the auxiliary and secondary windings respectively. Thus measuring the voltage produced by the auxiliary winding is comparable to e.g. taking a sample from the actual bus voltage with a voltage divider; however the former can be accomplished with components exclusively on the primary side.

[0023] In the schematic approach of fig. 2 the operating voltage required by the primary side controller 207 comes from the input voltage of the power supply, or from elsewhere in the power supply. However, in many cases the operating voltage levels specified for microcontrollers or other circuit elements that can be used as the primary side controller are very much smaller than the internal DC voltages that appear at various parts of the power supply. Therefore the auxiliary voltage produced to the primary side controller 207 at the point schematically illustrated as 306 in fig. 3 may simultaneously be an operating voltage of the primary side controller 207; by suitably selecting the numbers of turns of the various coils in the isolation transformer 203 it can be ensured that the level of the auxiliary voltage is more suitable for use as an operating voltage of a microcontroller than the level of those voltages that are typically encountered in the power supply.

[0024] Fig. 4 illustrates schematically an example of an approach of deriving a standby command on the primary side from an observed decrease in an auxiliary voltage that as such serves as an indirect representative of the bus voltage. Fig. 4 can be considered as a block diagram of a hardware implementation or as a flow diagram that describes a method.

[0025] We may assume that the driver device is capable of producing a bus voltage on a galvanically isolated secondary side. Blocks 401 and 402 in fig. 4 illustrate utilizing feedback from the secondary side to the primary side of the driver device. During normal operation the feedback coupling is used for bus voltage feedback. In other words, a sample of the bus voltage is taken to block 401 where bus voltage feedback is generated for conveying over the borderline 106 to the primary side. A bus voltage feedback value is provided from block 402 to the primary side controller 207, which uses it to control the way in which the power supply produces the bus voltage.

[0026] A secondary side controller 205 on the secondary side is capable of producing a standby command for use on the secondary side. The standby command may be used for example to shut down all switching in the switched-mode power supplies that form the output voltage(s) in the output stage(s), and/or to otherwise ensure that no light is produced during standby mode. According to fig. 4 the standby command issued by the secondary side controller 205 also affects the way in which bus voltage feedback is generated in block 401; in particular it may cause the generated bus voltage feedback to be "exaggerated" so that eventually the feedback from the secondary side to the primary side of the driver device will be utilized to make the primary side controller 207 decrease the bus voltage during standby mode.

[0027] Fig. 5 illustrates one possible way of making a standby command from the secondary side controller 205 affect the way in which bus voltage feedback is generated. The voltage feedback arrangement comprises an optocoupler 501 with a photodiode that has an anode and a cathode. A coupling exists (through a resistor) between a first lower (15 V) voltage produced by the first voltage regulator 502 and the anode of said photodiode. The voltage feedback arrangement comprises a shunt regulator 503 coupled to the cathode of the photodiode, and a basic reference voltage coupling from the bus voltage VBUS through resistors 504 and 505 to a control input of the shunt regulator 503. Resistor 506 complements the voltage divider that brings a scaled sample of the bus voltage VBUS to the control input of the shunt regulator 503.

[0028] During normal operation the scaled sample of the bus voltage VBUS controls the shunt regulator 503 so that the higher the bus voltage VBUS becomes, the more current is drawn through the photodiode in the optocoupler 501, and consequently the more photons the photodiode emits inside the optocoupler. Correspondingly if the bus voltage VBUS would tend to drop too low, the scaled sample thereof would also decrease, decreasing the current through the photodiode and making it shine dimmer.

[0029] The secondary side controller (which is not shown in fig. 5 but is supposed to be capable of producing a standby signal STANDBY) is configured to implement the change of the way in which the feedback signal represents the bus voltage VBUS by changing the conductivity of a coupling between a second lower (3.3 V) voltage and the control input of the shunt regulator 503. The second lower (3.3 V) voltage is produced somewhere on the secondary side, for example with a linear regulator coupled to the bus voltage or to the first lower (15V) voltage. A simple transistor circuit acts as a switch 507. The polarity of the standby signal STANDBY is such that when activated (i.e. when the standby signal STANDBY signifies that the driver device should be in standby state) it is low, making the transistor conductive in the switch 507 and allowing some current to flow from the second lower (3.3 V) voltage to the control input of the shunt regulator 503. This causes an overall increase to the electric potential of the control input, which results in an "exaggerated" voltage feedback signal.

[0030] Referring back to fig. 4, block 403 represents creating or generating an auxiliary voltage; more generally it can be considered to represent creating a voltage that somehow represents the actual bus voltage value. In fig. 4 the created auxiliary voltage is taken as the operating voltage VCC to the primary side controller 207. Additionally the driver device comprises a comparator 404 that is configured to compare a magnitude of the auxiliary voltage or a sample thereof to a reference voltage, and to produce a standby command STBY to the primary side controller as a response to the auxiliary voltage or sample thereof being smaller than the reference voltage. A separate comparator 404 is not needed, if the primary side controller 207 is itself capable of internally measuring the voltage it receives at the input marked VCC in fig. 4, or at least capable of comparing such voltage to a reference voltage or otherwise deducing whether it is on a normal level or on a reduced level.

[0031] Fig. 6 illustrates an example of a primary side (and some parts of the secondary side) of a driver device. The block that has been referred to generally as the power supply above comprises here a series coupling of a power factor correction (PFC) converter 601 and a second converter 602, which in this case is a flyback converter. The auxiliary voltage generation block 403 comprises an auxiliary winding that is wound on the same core as the primary and secondary windings of the isolation transformer, and has the same polarity as the secondary winding. The comparator 404 is configured to compare a sample of the auxiliary voltage, taken through the voltage divider 603, to a reference voltage formed with a simple zener diode coupling. If the decrease in the bus voltage VBUS is sufficiently large, it is reflected with similarly large relative decreases in the auxiliary voltage and in the sample taken thereof respectively, so that the output of the comparator 404 gives a standby command to the primary controller 207.

[0032] The connections that are graphically shown at the upper edge of the primary side controller 207 in fig. 6 are, from left to right: a monitor input for monitoring the current drawn from the input section 101; a switching pulse output for repeatedly making the power switch in the PFC converter 601 conductive and non-conductive; a monitor input for monitoring the current through the power switch in the PFC converter 601; a switching pulse output for repeatedly making the power switch in the second converter 602 conductive and non-conductive; and a monitor input for monitoring the current through the power switch in the second converter 602.

[0033] Comparing fig. 6 to fig. 4, the output from the primary controller 207 that is said to represent control of VBUS in fig. 4 could be taken to correspond to the switching pulse output for repeatedly making the power switch in the second converter 602 conductive and non-conductive in fig. 6. The primary side controller 207 can control the generation of the bus voltage by controlling the duty cycle, frequency, and/or other characteristics of the switching pulses that are delivered to the control electrode (gate) of the power switch in the second converter 602. The output from the primary controller 207 that is said to represent the further standby function on the primary side in fig. 4 could be taken to correspond to the switching pulse output for repeatedly making the power switch in the PFC converter 601 conductive and non-conductive in fig. 6.

[0034] An example of at least one further standby mode function that the primary side controller 207 may make the power supply implement as a response to a decreasing value of the bus voltage is partially or completely deactivating the PFC converter 601. In other words, when the output of the comparator 404 gives a standby command, the primary side controller 207 may temporarily halt all switching pulses to the power switch in the PFC converter 601. As a result, the internal DC voltage at the output of the input section 101 may pass directly through the PFC converter 601, become filtered by the inductive and capacitive components therein, and act as an input voltage to the second converter 602. Not applying power factor correction during standby mode may be acceptable, because such a small amount of power will be drawn by the driver device anyway that any distorting effects in power factor have negligible effect. At the same time a significant portion of switching losses and other losses that would otherwise be caused in the PFC converter are avoided, which helps to reduce energy consumption during standby mode. Partially deactivating the PFC converter would mean only issuing switching pulses according to some constant manner that has been considered most energy-effective, regardless of whether it helps to compensate for power factor distortions.

[0035] The dimensioning of the auxiliary voltage creation block 403 should take into account that also during standby mode, when the secondary side controller has utilized the feedback coupling to make the primary side controller 207 decrease the bus voltage, the primary side controller 207 should remain operative at least to the extent that it can make the power supply provide at least some electric power through the isolation transformer to the secondary side. In other words, also during standby mode the auxiliary voltage (which is proportional to the bus voltage) must remain within a range of allowable operating voltages of the primary side controller 207. However, many microcontrollers of the kind that can be used as primary side controllers are relatively flexible regarding their allowable operating voltage, so it is relatively easy to dimension the auxiliary voltage creation block so that the auxiliary voltage remains within the range of allowable operating voltages both during normal mode (when the auxiliary voltage reflects the full value of the bus voltage) and during standby mode (when the auxiliary voltage reflects the decreased value of the bus voltage).

[0036] A hardware designer designing a driver device may use an off-the-shelf integrated circuit as the primary side controller. Many manufacturers offer dedicated controller circuits for this purpose. However, some controller circuits of this kind have been observed to operate in a manner that may cause problems related to unintended switching off of the PFC converter. Namely, some of these controller circuits are designed to partially or completely deactivate the PFC converter of the power supply when the transmitted power, i.e. the power that the second converter transfers over the isolation transformer, becomes smaller than some predetermined limit. In a controllable LED driver such circumstances may occur when the LEDs are dimmed to low intensity but not completely extinguished.

[0037] In a driver device such as that (a part of which is) illustrated in fig. 6, the transmitted power feedback circuit comprises the current sensing resistor on the current path that goes through the power switch in the second converter 602, as well as the coupling from the node between said current sensing resistor and said power switch to the appropriate monitor input of the primary side controller (the rightmost connection at the top edge of the primary side controller 207 in fig. 6). The transmitted power is proportional to the square of the peak current on the main current path through the primary winding, the power switch, and the current sensing resistor. By observing the peak voltage across the current sensing resistor in each switching cycle the primary side controller can calculate a value that indicates the transmitted power.

[0038] If the transmitted power is relatively small, such as for example when the LEDs are dimmed to a low level and only consume a relatively small amount of power, the peak current - and hence the peak voltage that the primary side controller observes across the current sensing resistor - also remains small. The off-the-shelf integrated circuit may have been configured to interpret such a small transmitted power as a reason for shutting down the PFC converter. However, under the conditions described above this may lead to a situation where the LED driver does not meet the specifications concerning its connection to the mains grid at all power levels. There exists a need to keep the PFC converter operative under low-load conditions, while simultaneously ensuring that it will be shut down during standby mode, even if as such the primary side controller would be adapted to partially or completely deactivate power factor correction on the primary side as a response to a transmitted power feedback value reaching or exceeding a predetermined limit.

[0039] This objective can be met by using a specific circuit adapted to "artificially" keep the transmitted power feedback value from reaching or exceeding said predetermined limit during operation of the driver device when the primary side controller has not decreased the bus voltage in association with standby mode, and to allow the transmitted power feedback value to reach or exceed said predetermined limit during operation of the driver device when the primary side controller has decreased said bus voltage in association with standby mode.

[0040] Fig. 7 illustrates schematically an example of an approach of keeping the transmitted power feedback value from reaching the limit when PFC should run continuously, while allowing the transmitted power feedback value to reach the limit in standby mode. Fig. 7 can be considered as a block diagram of a hardware implementation or as a flow diagram that describes a method.

[0041] Blocks 207, 402, 403, and 404 can be the same as the correspondingly numbered blocks in fig. 4. A transmitted power feedback circuit, or the method steps to provide the primary side controller 207 with a transmitted power feedback value, comprise blocks 701 and 702. Of these, block 701 may make use of e.g. a switch current indicator coupling adapted to produce a switch current indicator value indicative of a current through a power switch in the power supply. Block 702 may make use of a biasing circuit that is configured to augment the switch current indicator value with a bias value, which is indicative of a difference between the bus voltage and the bus voltage feedback value. Of these the former (or a value indicative of the former) comes from block 403, and the latter comes from block 402. The switch current indicator value from block 701 augmented with the bias value in block 702 becomes the transmitted power feedback value that is provided to the primary side controller 207.

[0042] Fig. 8 illustrates an exemplary practical implementation of the principle explained above with reference to fig. 7. The main current path of the second converter in the power supply goes through the primary winding 801, the power switch 802, and the current sensing resistor 803. The switch current indicator coupling comprises a coupling from said main current path, along which the power switch 802 is located, through resistor 804 to the current feedback input of the primary side controller 207. The auxiliary voltage that is generated in block 403 serves as an indicator of the bus voltage, as has been described earlier, so the potential at the node between the capacitor and diode in block 403 is proportional to the bus voltage. On the other hand a bus voltage feedback value is provided from the secondary side through the optocoupler 501.

[0043] Components in the circuit of fig. 8 that correspond to block 702 in fig. 7 are the resistors 805 and 806, the zener diodes 807 and 808, and the transistor 809. Together these components may be called a biasing circuit, and the combination of the zener diode 807 and the transistor 809 constitute a biasing switch. The biasing circuit comprises a coupling from the potential proportional to the bus voltage through the zener diode 807 (in reverse direction), the transistor 809, and the resistor 805 to the current feedback input of the primary side controller 207. The biasing switch consisting of the zener diode 807 and transistor 809 is adapted to become conductive as a response to a decreasing bus voltage feedback value, and to become non-conductive as a response to said potential proportional to the bus voltage becoming smaller than a predetermined limit.

[0044] The operation of the relevant parts of the circuit of fig. 8 can be explained in other words as follows. During normal operation when the transmitted power is relatively large, the peak voltage values that can be observed across the current sensing resistor 803 are also relatively large. These peak voltage values are coupled through resistor 804 to the current feedback input of the primary side controller 207, which deduces that transmitted power is large and that the PFC converter must be kept running.

[0045] Even when the LEDs are dimmed and consequently consume only relatively little power, the bus voltage must be kept at its original value (the LEDs are typically dimmed through pulse width modulation or amplitude limitation of the current through them, while the voltage across the whole LED chain must remain equal to the sum of voltage drops across all LEDs, which essentially leads to a requirement of constant bus voltage). Thus even under low-power (but not-standby-mode) conditions the auxiliary voltage generated in block 403 remains relatively large; i.e. the potential at the cathode of zener diode 807 remains relatively high and the voltage across said zener diode 807 remains above its reverse threshold voltage. On the other hand, low-power conditions mean that the bus voltage feedback value that can be observed on the line connecting the optocoupler 501 to the bus voltage feedback input of the primary side controller 207 becomes smaller.

[0046] At some point the potential at the base of the transistor 809 is low enough to make the transistor 809 conductive, so that a bias value that is indicative of a difference between the bus voltage (represented indirectly by the auxiliary voltage) and the bus voltage feedback value becomes coupled through resistor 805 to the output of the switch current indicator coupling. Said bias value thus augments the actual switch current indicator value; the switch current indicator value augmented with the bias value now constitutes the transmitted power feedback value seen by the primary side controller 207. In its augmented form the transmitted power feedback value is larger than it would be without the biasing circuit, so the primary side controller 207 does not recognize the present operating state as such a low-power state that would call for shutting off the PFC converter.

[0047] Above it was already noted that the secondary side controller is adapted to utilize the feedback coupling through optocoupler 501 to make the primary side controller 207 decrease the bus voltage during standby mode. A decreasing bus voltage means a decreasing auxiliary voltage at block 403, i.e. a lower potential at the cathode of the zener diode 807. The reverse voltage across said zener diode 807 becomes thus smaller than its reverse threshold voltage, and consequently the zener diode 807 becomes non-conductive in the reverse direction. The biasing upwards of the transmitted power feedback value vanishes, and the primary side controller 207 is free to shut down the PFC controller.

[0048] The circuit of fig. 8 is shown to also include the functions that were built around the comparator 404 and explained earlier with reference to figs. 2 to 6, but it should be noted that the principle that has been explained above with reference to figs. 7 and 8 can be applied also independently. In other words, it is not mandatory to make the power supply implement the at least one further standby mode function as a response to a decreasing value of the bus voltage, if e.g. the switching off of the PFC converter can be completely controlled in all circumstances with the principle of figs. 7 and 8. It is also possible to use the principle of figs. 7 and 8 to control the switching off of the PFC converter during standby mode, and to make the power supply implement some yet further standby mode function as a response to a decreasing value of the bus voltage, with the help of the comparator 404 or a correspondingly operating circuit.

[0049] The exemplary embodiments described above do not constitute an exhaustive or limiting description of the scope of protection defined by the appended claims, but variations and modifications are possible. For example, the PFC converter and second converter in the power supply may follow other converter topologies than what have been described, and there may be more windings in the isolation transformer than what has been described. As an example of the last-mentioned alternative, the driver device may have two or more output stages that each have their own secondary windings in the isolation transformer (although two- or multi-channel driver devices can also have a shared secondary winding in the isolation transformer, so that the same bus voltage nodes serve the bus voltage to all parallel output stages). An optocoupler is not the only possible way of conveying feedback across a borderline between galvanically isolated parts, and the changes in the way in which the bus voltage feedback signal reflects the actual bus voltage can be implemented with e.g. switch networks or other kinds of circuits different than the one described above.

Claims

1. A driver device for light-emitting means, comprising:

- a primary side adapted to receive an input voltage,
- a secondary side adapted to produce an output voltage, the secondary side being galvanically isolated from the primary side,
- a power supply adapted to produce a bus voltage for the secondary side, with an isolation transformer (203) of said power supply bridging the borderline between the primary and secondary sides,
- on the primary side a primary side controller adapted to control said power supply,
- on the secondary side a secondary side controller, and
- a feedback coupling from said secondary side to said primary side;

wherein said secondary side controller is adapted to utilize said feedback coupling to make the primary side controller decrease said bus voltage during standby mode, and wherein said primary side controller is adapted to make said power supply implement at least one further standby mode function as a response to a decreasing value of said bus voltage.

2. A driver device according to claim 1, comprising an auxiliary winding in said isolation transformer for producing an auxiliary voltage to said primary side controller, wherein said primary side controller is adapted to detect said decreasing value of the bus voltage indirectly through a decrease in said auxiliary voltage.

3. A driver device according to claim 2, wherein said auxiliary voltage is an operating voltage of said primary side controller.

4. A driver device according to claim 2 or 3, comprising a comparator configured to compare a magnitude of said auxiliary voltage or a sample thereof to a reference voltage and to produce a standby command to said primary side controller as a response to said auxiliary voltage or sample thereof being smaller than said reference voltage.

5. A driver device according to any of the preceding claims, wherein:

- the power supply comprises a series coupling of a power factor correction converter and a second converter, and
- said at least one further standby mode function comprises partially or completely deactivating said power factor correction converter.

6. A driver device according to any of the preceding claims, comprising a transmitted power feedback circuit adapted to provide said primary side controller with a transmitted power feedback value, wherein:

- the primary side controller is adapted to partially or completely deactivate power factor correction on said primary side as a response to said transmitted power feedback value reaching or exceeding a predetermined limit, and
- said transmitted power feedback circuit is adapted to keep said transmitted power feedback value from reaching or exceeding said predetermined limit during operation of the driver device when the primary side controller has not

decreased said bus voltage in association with standby mode, and to allow said transmitted power feedback value to reach or exceed said predetermined limit during operation of the driver device when the primary side controller has decreased said bus voltage in association with standby mode.

7. A driver device according to claim 6, comprising:

- on the primary side a switch current indicator coupling adapted to produce a switch current indicator value indicative of a current through a power switch in said power supply,
- on the primary side a biasing circuit, and
- on the secondary side a bus voltage feedback circuit;

wherein said bus voltage feedback circuit is adapted to utilize said feedback coupling to provide said primary side controller with a bus voltage feedback value, and wherein said biasing circuit is configured to augment said switch current indicator value with a bias value indicative of a difference between said bus voltage and said bus voltage feedback value, and wherein said switch current indicator value augmented with said bias value constitutes said transmitted power feedback value.

8. A driver device according to claim 7, wherein:

- said switch current indicator coupling comprises a coupling from a current path, along which said power switch is located, to a current feedback input of said primary side controller,
- said biasing circuit comprises a coupling from a potential proportional to the bus voltage through a biasing switch to said current feedback input, and
- said biasing switch is adapted to become conductive as a response to a decreasing bus voltage feedback value, and to become non-conductive as a response to said potential proportional to the bus voltage becoming smaller than a predetermined limit.

9. A method for operating a driver device for light-emitting means, comprising:

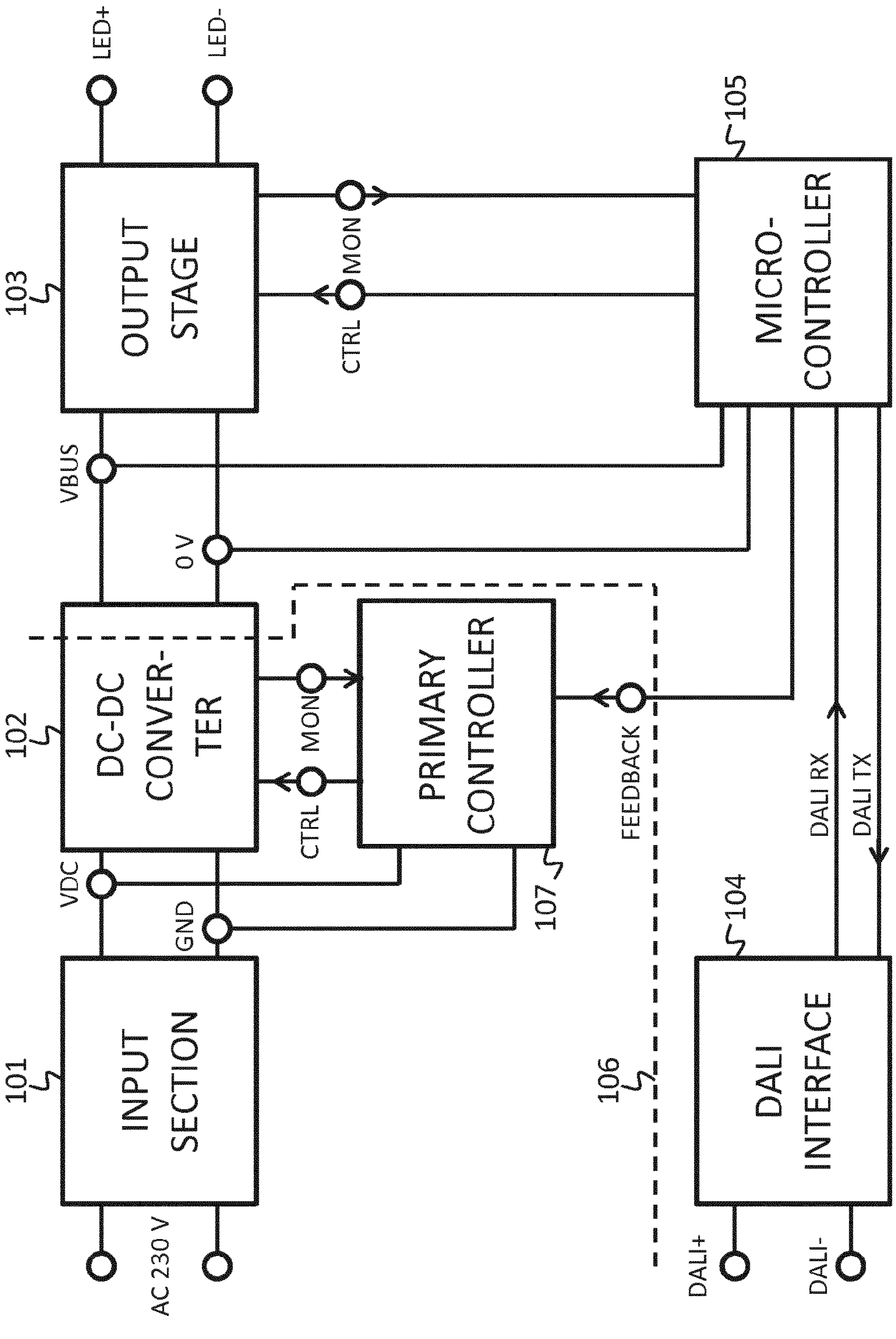
- producing a bus voltage on a galvanically isolated secondary side of the driver device,
- utilizing feedback from the secondary side to a primary side of the driver device to make a primary side controller decrease said bus voltage during standby mode, and
- implementing, through actions of said primary side controller, at least one further standby mode function on the primary side as a response to a decreasing value of said bus voltage.

10. A method according to claim 9, wherein said at least one further standby mode function on the primary side comprises partially or completely deactivating a power factor correction converter.

11. A method according to any of claims 9 or 10, wherein a decreasing value of the bus voltage is detected indirectly through a decrease in an auxiliary voltage produced by an auxiliary winding in an isolation transformer bridging the borderline between the primary and secondary sides.

12. A method according to any of claims 9 to 11, comprising:

- partially or completely deactivating power factor correction on said primary side as a response to a transmitted power feedback value reaching or exceeding a predetermined limit,
- keeping said transmitted power feedback value from reaching or exceeding said predetermined limit during operation of the driver device when the primary side controller has not decreased said bus voltage in association with standby mode, and
- allowing said transmitted power feedback value to reach or exceed said predetermined limit during operation of the driver device when the primary side controller has decreased said bus voltage in association with standby mode.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LED-
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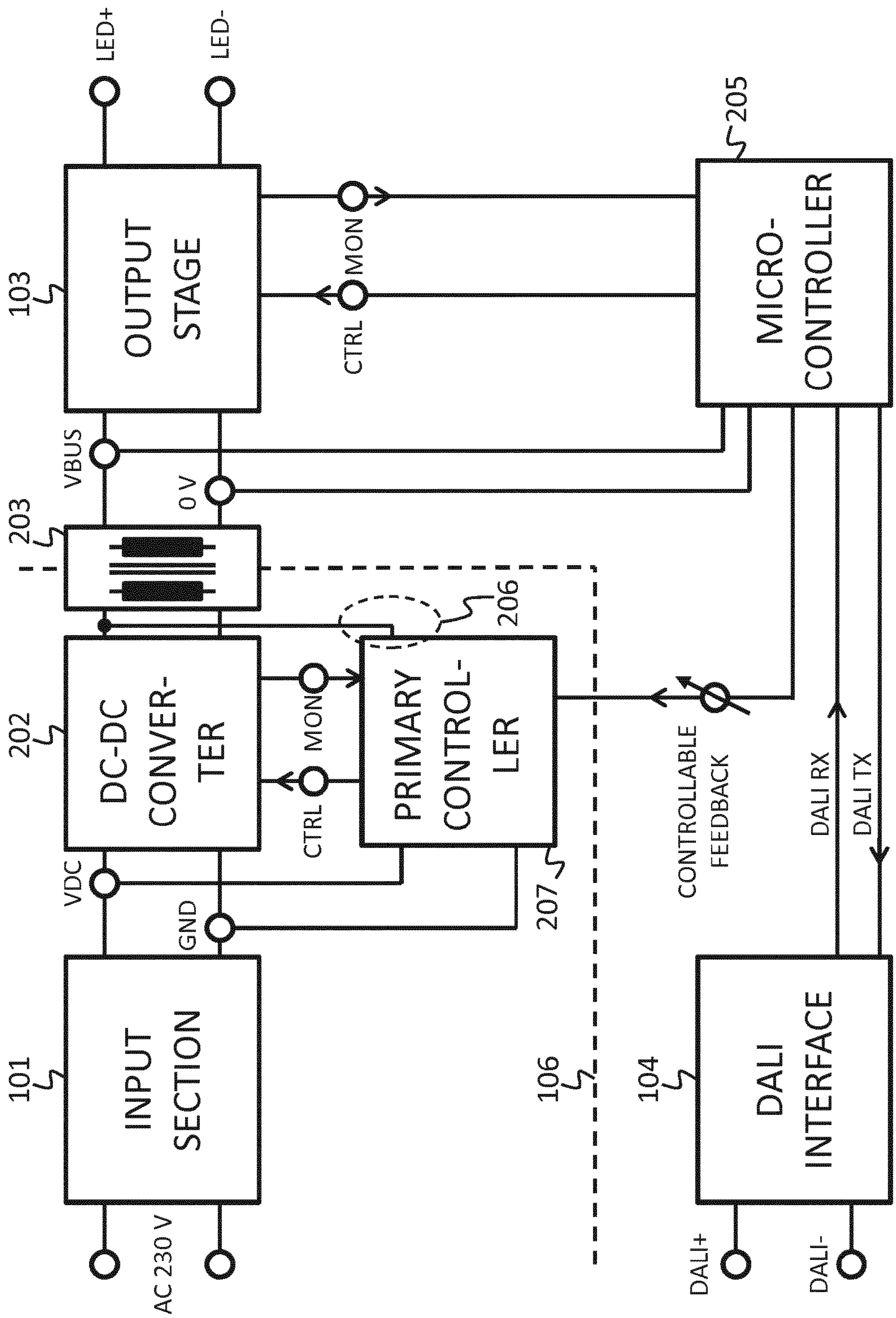
VBUS
0 V
102
DC-DC CONVER-TER
MON
CTRL
PRIMARY CONTROLLER
FEEDBACK
107
VDC
GND
101
INPUT SECTION
AC 230 V
106
104
DALI INTERFACE
DALI RX
DALI TX
DALI+
DALI-

Fig. 1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202
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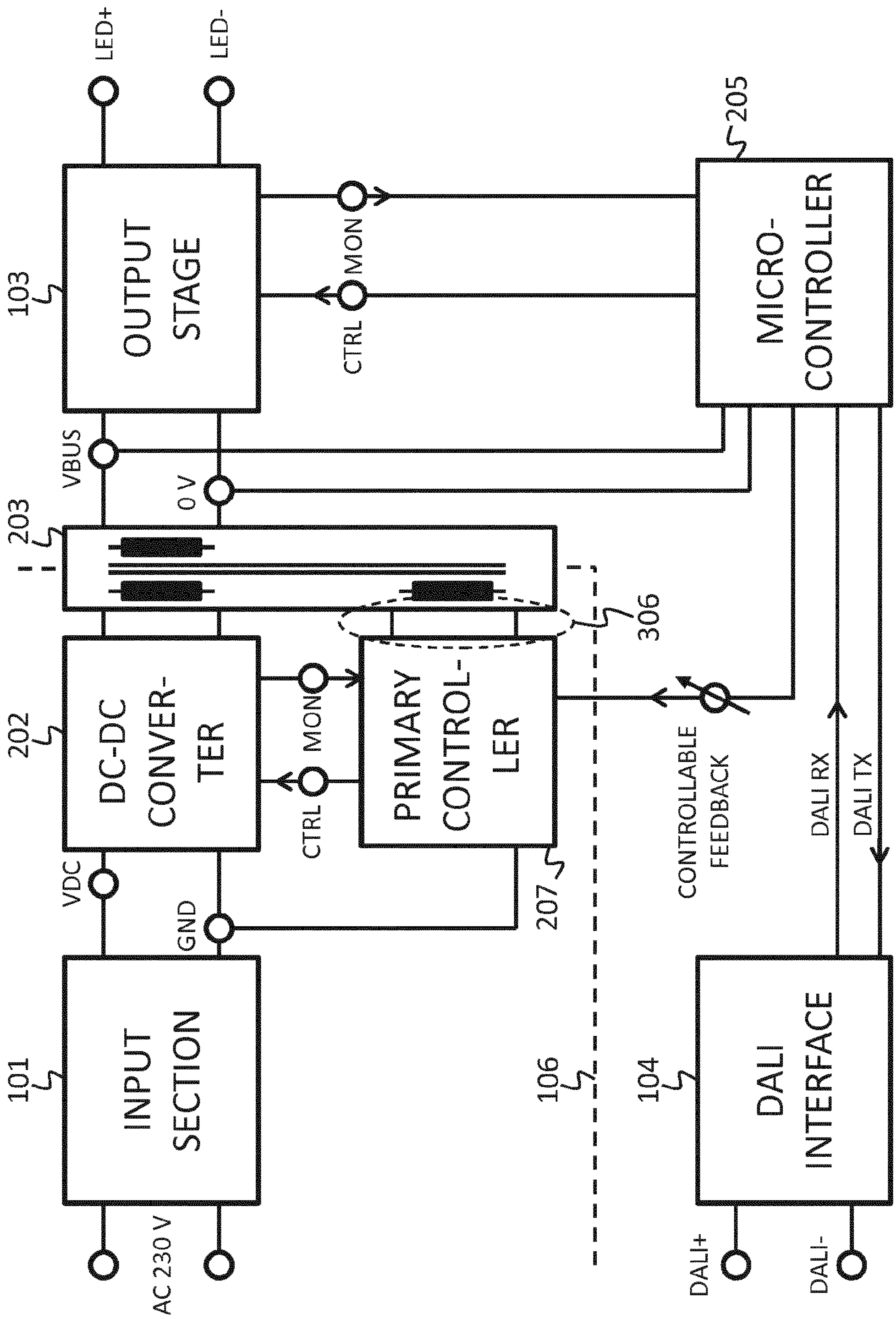
MON
CTRL
PRIMARY CONTROL- LER
207
VDC
GND
CONTROLLABLE FEEDBACK
DALI RX
DALI TX
101
INPUT SECTION
106
104
DALI INTERFACE
AC 230 V
DALI+
DALI-

Fig. 2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VDC
GND
CONTROLLABLE FEEDBACK
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INPUT SECTION
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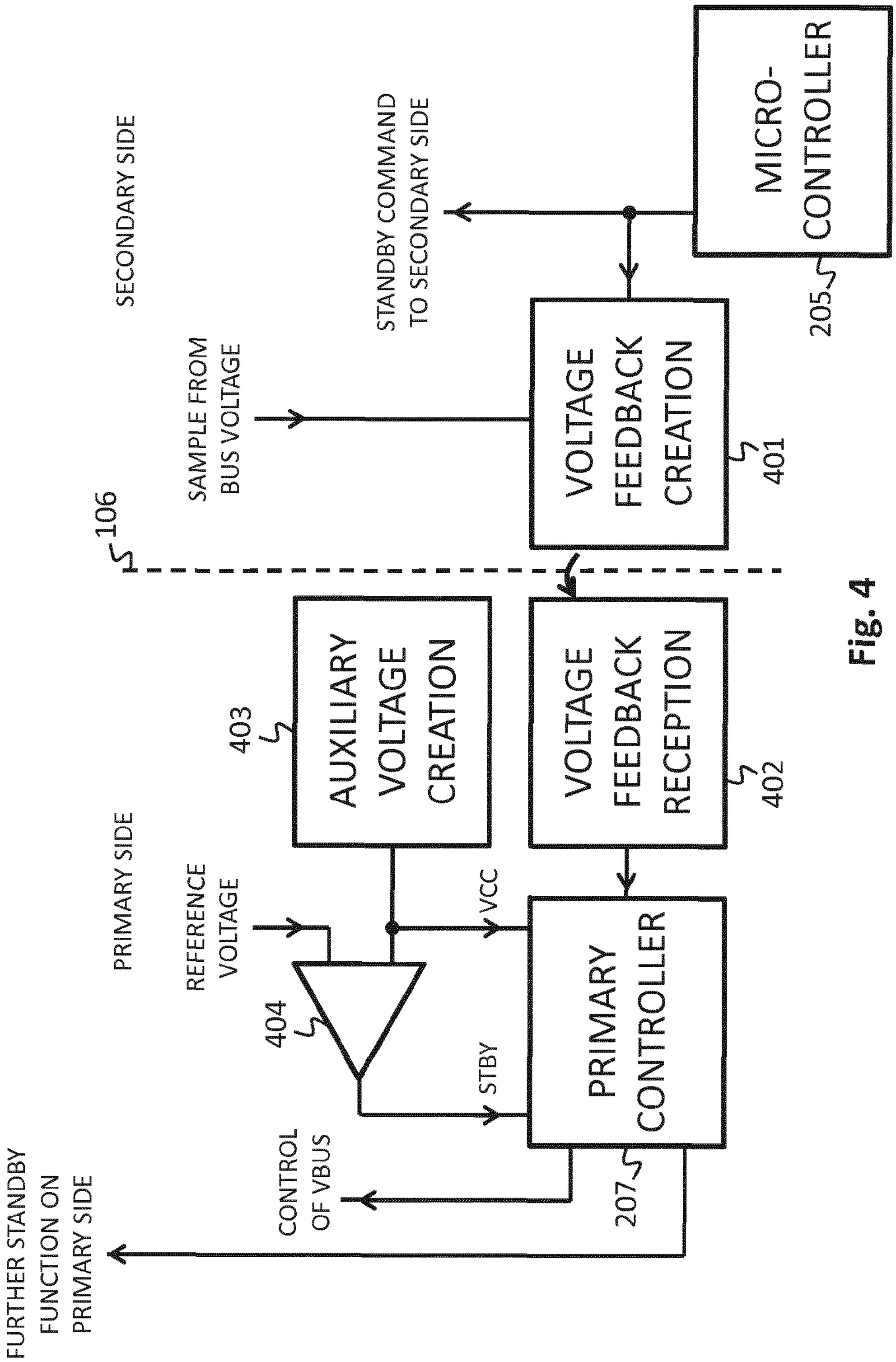
106
104
DALI INTERFACE
DALI+
DALI-

Fig. 3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PRIMARY SIDE
STANDBY COMMAND TO SECONDARY SIDE
MICRO-CONTROLLER
205
SAMPLE FROM BUS VOLTAGE
VOLTAGE FEEDBACK CREATION
401
106
AUXILIARY VOLTAGE CREATION
403
VOLTAGE FEEDBACK RECEPTION
402
REFERENCE VOLTAGE
404
VCC
STBY
PRIMARY CONTROLLER
207
CONTROL OF VBUS
FURTHER STANDBY FUNCTION ON PRIMARY SIDE

Fig. 4

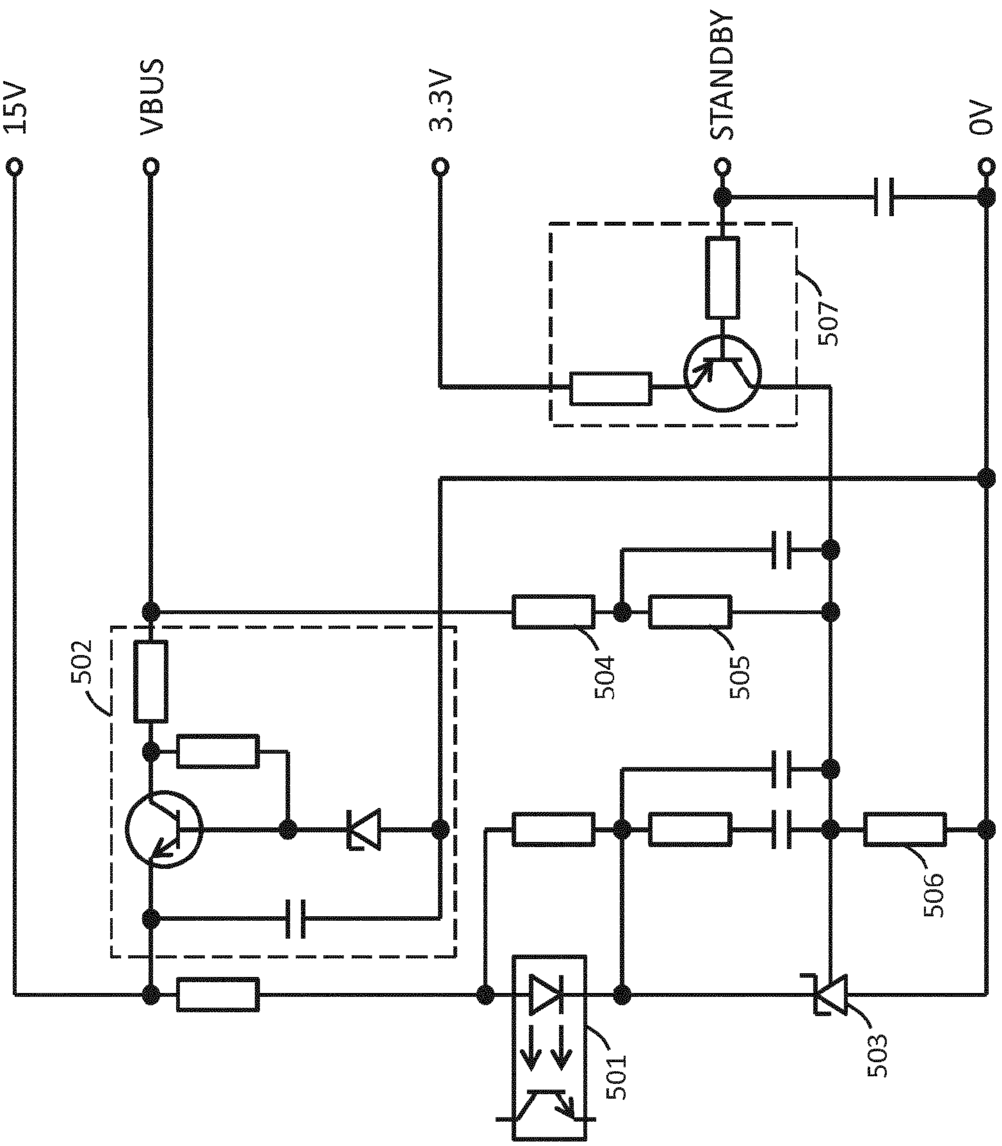
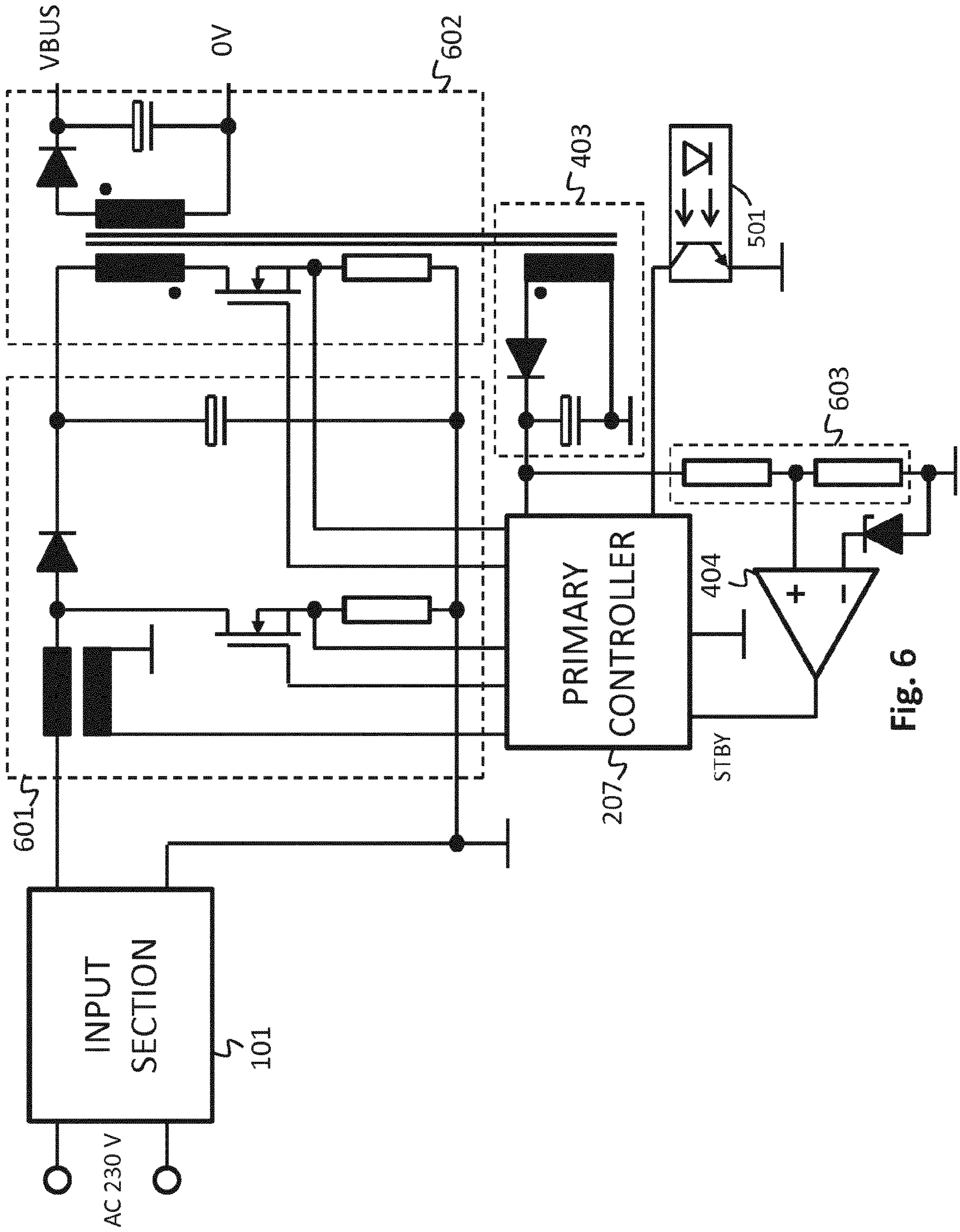


Fig. 5


VBUS
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PRIMARY CONTROLLER
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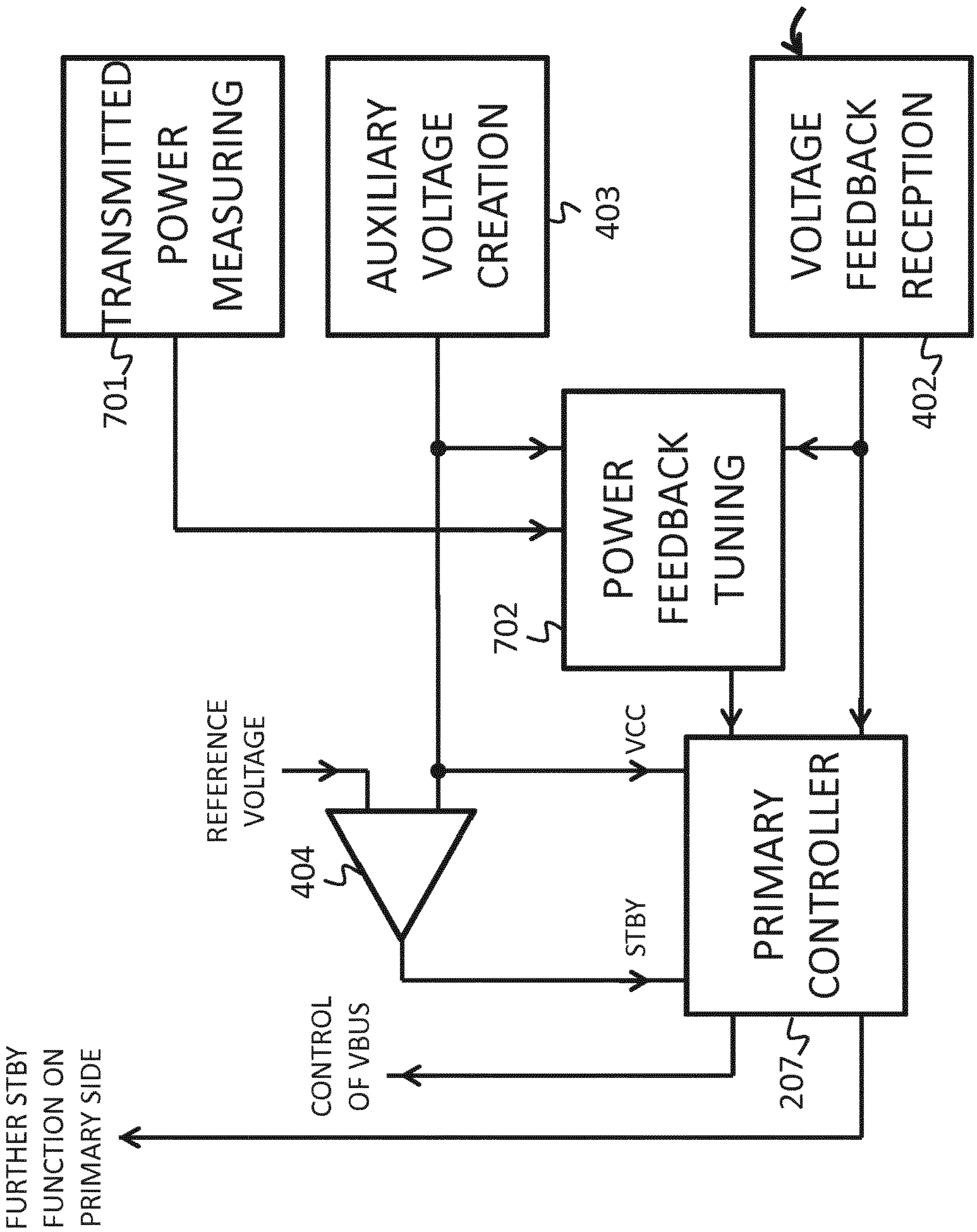
AC 230 V

Fig. 6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701
AUXILIARY VOLTAGE CREATION
403
VOLTAGE FEEDBACK RECEPTION
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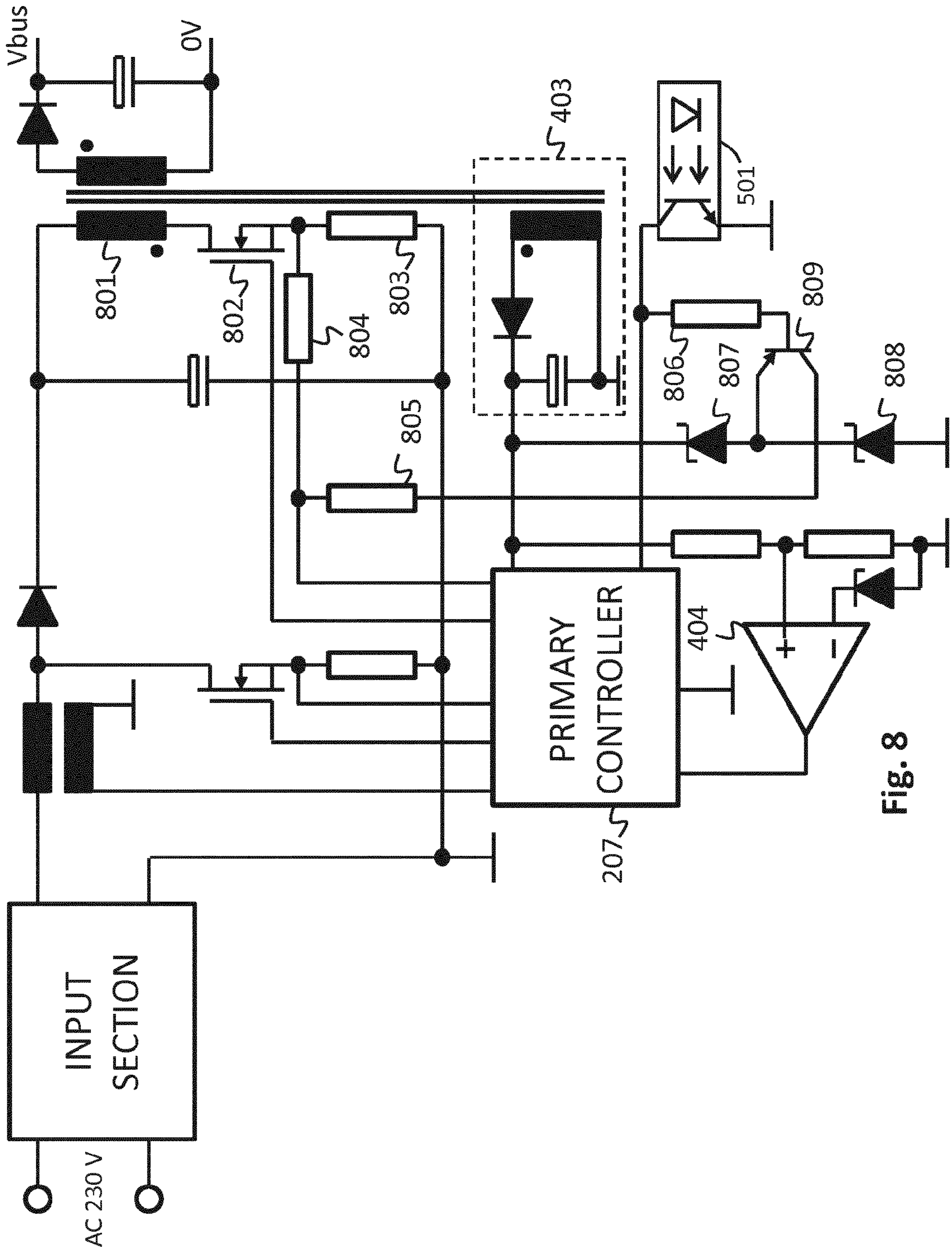
VCC
STBY
PRIMARY CONTROLLER
207
CONTROL OF VBUS
FURTHER STBY FUNCTION ON PRIMARY SIDE

Fig. 7


Vbus
0V
403
501
801
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806
807
808
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PRIMARY CONTROLLER
207
INPUT SECTION
AC 230 V

Fig. 8

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EUROPEAN SEARCH REPORT

Application Number
EP 15 15 7299

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H05B

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	12 August 2015	Morrish, Ian

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12-08-2015

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