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(54) Driver circuit for driving a lighting device and method for operating the same

(57) The invention provides a driver circuit for driving a lighting device, for being connected between a dimmed supply voltage and said lighting device. The driver circuit comprises a first bleeder resistor, which has a first end connected to a high-voltage terminal of the supply voltage, a second bleeder resistor, which has a first end connected to a low-voltage terminal of the supply voltage, a first semiconductor switching element connected between the second ends of the first and second bleeder resistors, and a second semiconductor switching element connected between the second end of the second bleeder resistor and the low-voltage terminal of the supply voltage. Under a further aspect, the invention provides a method for operating such a driver circuit. The method comprises detecting a predefined low-current phase of an input current of the driver circuit, the input current being below a predefined current threshold and the supply voltage being not below a predefined voltage threshold during the low-current phase. In a further step, upon detecting the low-current phase, a voltage drop across the second bleeder resistor is regulated during the low-current phase.

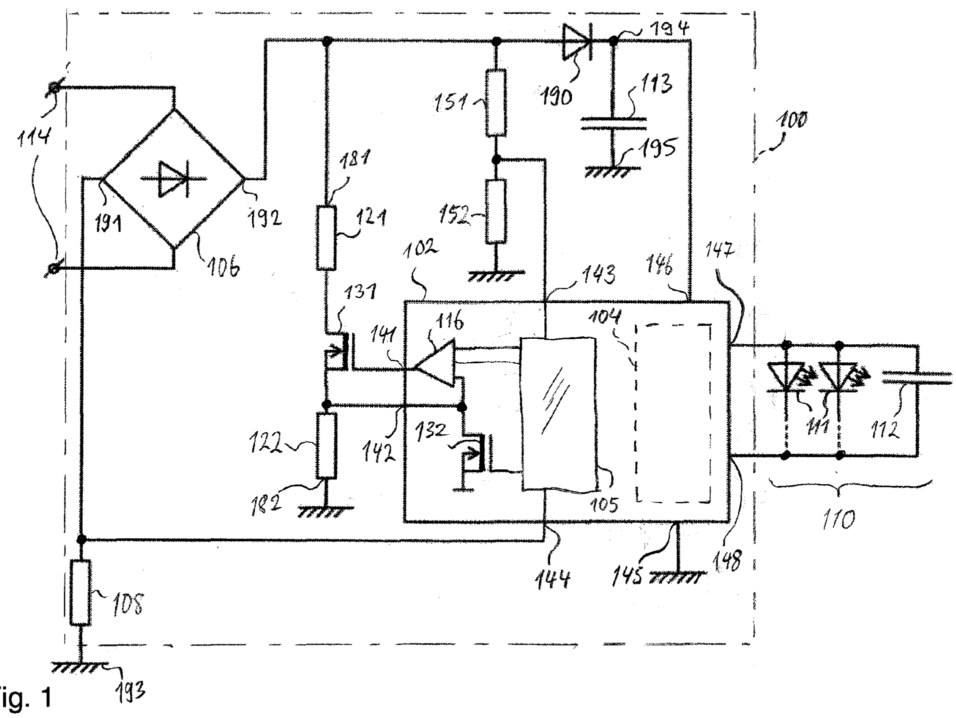

Fig. 1

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Description

Background

[0001] The present invention relates to a driver circuit for driving a lighting device, in particular a lighting device including an energy-saving lighting element such as a light emitting diode. Under further aspects, the invention relates to a lighting device comprising a lighting element and such a driver circuit, and to a method for operating such a driver circuit.

[0002] In order to reduce the overall energy expended for lighting purposes, various forms of energy-efficient lighting technologies such as based on light emitting diodes (LEDs) are currently being developed as a replacement for conventional incandescent lighting. To reduce the cost of replacing conventional lighting devices with lighting devices based on new technology, it is desirable to provide such new lighting devices in forms that a compatible mechanically, electrically, and thermally with conventional lighting devices. In this way, a consumer may benefit from energy savings without having to make changes to related equipment such as sockets, lamp shades, or wall based electric installations.

[0003] A particular problem arises when energy-saving lighting devices are to be used as replacements for a conventional lighting devices connected to a dimmer. Typical dimmers, which are common parts of wall-based electrical installations in households, generate a lower average voltage than a mains voltage by means of phase-cut circuitry. During a first part of the sinusoidal mains voltage after a zero crossing of the sine wave, a switching triac or transistor in the dimmer circuitry is non-conductive. After a customer-adjustable phase is reached, the triac or transistor is triggered to become conductive, conducting the mains voltage to the lighting device until the triac or transistor reverts to its non-conductive state at the next zero crossing of the sine wave. Typically, such dimmers require a minimum load of e.g. 40 W to be connected for stable operation. When an incandescent lamp of lower wattage than the minimum load is connected to the dimmer, instability of the dimmer circuitry due to inductive effects results in strong light flickering.

[0004] An energy-saving lighting device designed to replace an incandescent lamp or other conventional lighting device used with a dimmer will typically require less power than the minimum load specified by the dimmer. A simple approach to avoid flickering of the lighting device is to connect a bleeder resistor as a current sink in parallel to the lighting device such that the power consumption of the resistor and the lighting device combine to at least the minimum load. The increased power consumption, however, counteracts the energy saving purpose of the lighting device and is therefore highly undesirable.

[0005] The integrated LED driver circuit LM3445 by National Semiconductor (http://www.national.com/ds/LM/LM3445.pdf) includes a bleeder circuit to allow current flow through a bleeder resistor while the line voltage is below a fixed voltage threshold in order to enable proper firing of the dimmer triac. However, an external resistor representing a further current sink is needed to provide the triac with a holding current throughout the AC line cycle.

[0006] The integrated LED driver circuit SSL21 01 by NXP B. V. (http://www.nxp.com/documents/data_sheet/SSL2101.pdf) contains two current sinks that are called bleeders. A strong bleeder is used for zero cross reset of the dimmer and triac latching. A weak bleeder is added to maintain the hold current through the dimmer. The circuit includes two high-voltage transistor switches for switching the strong and weak bleeder resistors, respectively. The strong bleeder switch is switched on when a sensed voltage is lower than a predefined voltage level. The weak bleeder switch is switched on as soon as a sensed current drops below a predefined current level, and switched off when the sensed current exceeds a further predefined current level, or when the strong bleeder switch is switched on.

[0007] Because the strong and weak bleeders are switched on and off during different phases of the dimmed mains voltage, suppression of flickering is achieved at less consumption of energy compared to a solution where a single bleeder resistor is either permanently drawing current or switched on and off during a cycle of the dimmed mains voltage while a further resistor maintains a weaker hold current throughout the AC line cycle. However, the provision of two high-voltage switching transistors and resistors considerably increases production cost of the driver circuit. It is therefore an object of the invention to provide an improved driver circuit that enables sufficient suppression of flickering at both low production costs and low energy consumption.

Disclosure of the invention

[0008] Accordingly, a driver circuit is provided for driving a lighting device, for being connected between a dimmed supply voltage and said lighting device. The driver circuit comprises a first bleeder resistor, which has a first end connected to a high-voltage terminal of the supply voltage, a second bleeder resistor, which has a first end connected to a low-voltage terminal of the supply voltage, a first semiconductor switching element connected between the second ends of the first and second bleeder resistors, and a second semiconductor switching element connected between the second end of the second bleeder resistor and the low-voltage terminal of the supply voltage.

[0009] Because the second semiconductor switching element is connected between the first semiconductor switching element and the low-voltage terminal of the supply voltage, the first semiconductor switching element separates the second semiconductor switching element from the high-voltage terminal of the supply voltage in a state where the first semiconductor switching element is non-conductive. In another state where the first semiconductor switching element is conductive, the voltage across the second semiconductor switching element is below a semiconductor switching element control voltage by which the first semiconductor switching element is controllable. Thus, an upper limit of the semiconductor switching element control voltage represents a maximum voltage to which the second semiconductor switching element is exposable throughout both the non-conductive and conductive states of the first semiconductor switching element. This enables to implement the second switching element as a low-voltage type semiconductor switching element that is exposable to a proof voltage lower than the supply voltage, by configuring the control voltage for controlling the first semiconductor switching element to be less or equal to the proof voltage of the second semiconductor switching element.

[0010] Consequently, in the above driver circuit separately switchable week and strong bleeder functionality, which enables low energy consumption, is provided while requiring only a single high-voltage semiconductor switching element, i.e. only a single semiconductor switching element having a proof voltage that corresponds to a typical mains voltage in the range between 100 Vdc and 320 Vdc (corresponding to 240 Vac). Because low-voltage type semiconductor switching elements having a proof voltage of e.g. 40 V are manufacturable at considerably lower cost than high-voltage type semiconductor switching elements, manufacturing cost of the driver circuit is decreased over the prior art. Further cost advantages result since the second bleeder resistor is additionally enabled to be implemented as a low-voltage type resistance element.

[0011] According to a preferred development, the driver circuit further comprises a voltage detector for detecting whether or not the supply voltage is below a predefined voltage threshold, a current detector for detecting whether an input current of the driver circuit is below a predefined current threshold, and a controller for controlling the first and second semiconductor switching elements based on output of the voltage and current detectors. The controller is arranged to regulate a voltage drop across the second bleeder resistor when the supply voltage is not below the voltage threshold and the input current is below the current threshold. That is, week bleeding functionality is provided by stabilizing the voltage drop across the second bleeder resistor, which is proportional to the current passing through the second bleeder resistor. This leads to reduced energy consumption of the driver circuit because the current is kept constant at the level required for compatibility with the dimmer even when the supply voltage is high such as during power surges in the mains system.

[0012] According to a preferred development, the controller is arranged to switch the first semiconductor switching element to a non-conductive state when the input current is not below the current threshold. This enables to save energy by stopping all bleeding during a phase when the driver circuit draws sufficient current from the dimmer to prevent flickering.

[0013] According to a preferred development, the controller is arranged to switch the first and second semiconductor switching elements to a conductive state when the supply voltage is below the voltage threshold. This enables strong bleeding during a phase before the supply voltage rises due to latching of the dimmer triac or transistor. Since the supply voltage is close to zero during this phase, only little energy is consumed.

[0014] According to a preferred development, the controller comprises a differential amplifier, a first input of the differential amplifier being connected to the second end of the second bleeder resistor. This enables providing a regulation signal for regulating the week bleeding action. Preferably, an output of the differential amplifier is connected to an input of the first semiconductor switching element such that the first semiconductor switching element can be used for regulating the week bleeding action by regulating the voltage drop across the second bleeder resistor.

[0015] According to a preferred development, the current detector comprises a sensing resistor for sensing the input current of the driver circuit and a first Schmitt trigger for detecting a drop in the input current below the predefined current threshold. This enables to detect a crossing of the input current below the threshold in a simple and cost-effective way, using only low-voltage components.

[0016] According to another preferred development, the voltage detector comprises a voltage divider for deriving a sensing voltage from the supply voltage and a second Schmitt trigger for detecting a drop of the sensing voltage below said predefined voltage threshold. This enables to detect a crossing of the supply below the threshold in a simple and cost-effective way, using only low-voltage components.

[0017] According to a preferred development, the second semiconductor switching element and the controller are combined in an integrated circuit. This enables to keep production cost low because only a single integrated circuit has to be manufactured, and because low-energy technology may be used for manufacturing the integrated circuit.

[0018] According to a preferred development, the first semiconductor switching element and/or the second semiconductor switching element comprise a transistor, which are reliable and cost-efficient. In particular, if the first semiconductor switching element comprises a transistor, the voltage across the second semiconductor switching element will be below the voltage of a third control end of the first semiconductor switching element, i.e. of the gate or base of the transistor comprised by the first semiconductor switching element. This enables to implement the second semiconductor switching element as a low-voltage type semiconductor switching element that is exposable to a proof voltage lower than the supply voltage by making sure the voltage on the control end of the first semiconductor switching element is less or equal to the proof voltage. For example, each of the semiconductor switching elements may be implemented as a field effect transistor or a bipolar transistor.

[0019] Under a further aspect, the invention provides a lighting device comprising a lighting element and a driver circuit as described above, wherein the driver circuit is configured for driving the lighting element. This enables e.g. a consumer to conveniently install the lighting device without having to assemble or to separately connect the driver circuit and the lighting element. Preferably, the lighting element comprises at least one light emitting diode (LED), compact fluorescent lamp (CFL), cold cathode fluorescent lamp (CCFL), or halogen lamp in order to achieve particularly high efficiency of the lighting device.

[0020] Under a further aspect, the invention provides a method for operating such a driver circuit. The method comprises detecting a predefined low-current phase of an input current of the driver circuit, the input current being below a predefined current threshold and the supply voltage being not below a predefined voltage threshold during the low-current phase. In a further step, upon detecting the low-current phase, a voltage drop across the second bleeder resistor is regulated during the low-current phase. This enables to draw only the minimal hold current from the dimmer for the complete phase where week bleeding is required. The dimmer will stay switched on until the supply voltage is particularly close to the next zero crossing, such that even a very late phase cut of the dimmer can be detected with high precision, hence allowing for deeper dimming levels.

[0021] According to a preferred development, further steps are provided in which a predefined low-voltage phase is detected, the supply voltage being below the predefined voltage threshold during the low-voltage phase, and in which the first and second semiconductor switching elements are switched to a conductive state upon detecting the low-voltage phase. This enables strong bleeding before the supply voltage rises due to latching of the dimmer triac or transistor. Since the supply voltage is close to zero during low-voltage phase, only little energy is consumed while allowing proper latching of the triac in the dimmer.

[0022] According to a preferred development, the method comprises further steps of detecting a predefined high-current phase, the input current being not below the predefined current threshold during the high-current phase, and of switching the first semiconductor switching element to a non-conductive state upon detecting the high-current phase. This enables to save energy by stopping all bleeding when the driver circuit draws sufficient current from the dimmer for stable operation.

Brief description of the figures

[0023] Further aspects are illustrated in the accompanying drawing and described in detail in the following part of the description. In the figures,

Fig. 1 is a circuit diagram of a driver circuit for driving a lighting device according to an embodiment of the invention;

Fig. 2 is a circuit diagram of an integrated circuit for use in a driver circuit for driving a lighting device according to an embodiment;

Fig. 3A is a timeline diagram of a dimmed mains voltage;

Fig. 3B is a timeline diagram of the dimmed mains voltage of Fig. 3A after rectification, and of a stored voltage at a storage capacitor of the driver circuit of Fig. 1 driven by the dimmed mains voltage;

Fig. 3C is a timeline diagram of an input current of the driver circuit of Fig. 1 driven by the dimmed mains voltage of Fig. 3A; and

Fig. 4 is a flow diagram of a method of operating a driver circuit for driving a lighting device according to an embodiment.

[0024] Unless explicitly stated otherwise, throughout the figures the same reference numbers indicate the same or functionally equivalent means.

Detailed description

[0025] The circuit diagram of Fig. 1 shows a driver circuit 100 for driving a lighting device 110, which is exemplarily shown to comprise two light emitting diodes 111 connected in parallel to each other and to a decoupling capacitor 112 of the lighting device 110. The driver circuit 100 as shown is suitable for being used with other types of lighting devices, in particular those employing energy-saving lamp technologies such as compact fluorescent lamps (CFL), cold cathode fluorescent lamps (CCFL), and light emitting diodes (LED). The driver circuit 100 is furthermore suitable for use with any types of lighting device with small energy consumption such as halogen lamps of smaller wattage in order to make them compatible with standard wall dimmers. These lamps conventionally require installation of more advanced dimmers.

[0026] The driver circuit 100 comprises supply voltage connection terminals 114 for connection of the driver circuit 100 to a conventional dimmer (not shown) providing a dimmed mains voltage. The driver circuit 100 comprises a full-wave diode bridge rectifier 106 connected to the supply voltage connection terminals 114. A low-voltage output 191 of the rectifier 106 is connected to ground potential 193 via an input current sensing resistor 108. For example, a resistance of 100 Ω may be chosen for the input current sensing resistor 108, depending on the nominal power of the lighting device 110. A high-voltage output 192 of the rectifier 106 is connected via a diode

190 to a first end 194 of a storage capacitor 113, the other end 195 of which is grounded. The first end 194 of the storage capacitor 113 is furthermore connected to a high voltage supply terminal 146 of a power converter circuit, which here is exemplarily implemented as an integrated circuit 102 and includes general circuitry 104 such as e.g. a pulse width modulator for supplying the voltage received by the power converter circuit at the high-voltage supply terminal 146 and a ground terminal 145 to the lighting device 110 via first 147 and second 148 lighting device connection terminals of the power converter circuit. Since details of the general circuitry 104 are unrelated to the present invention, the general circuitry 104 is shown as an abbreviated outline only. In its simplest form, the general circuitry 104 may merely connect the storage capacitor voltage terminal 146 to the first lighting device connection terminal 147, and the ground terminal 145 to the second lighting device connection terminal 148. Also, the general circuitry 104 may comprise internal supply voltage generation components (not shown) for generating an internal supply voltage for the integrated circuit from the high voltage being initially supplied via the high-voltage supply terminal 146. In a simple case, such internal supply voltage generation components may consist e.g. of a resistor and a Zener diode connected in series. For example, the integrated circuit operates at an internal supply voltage of about 5 V while the voltage of the high-voltage supply terminal 146 is about 320 V.

[0027] The driver circuit 100 further comprises a first bleeder resistor 121, which has a first end 181 connected to the high-voltage output 192 of the rectifier 106, and a second bleeder resistor 122, which has a first end 182 connected to ground potential, i.e. to the low-voltage output 191 of the rectifier 106 via the sensing resistor 108. A high-voltage transistor 131 implementing a first semiconductor switching element of the driver circuit 100 is connected between the second ends of the first 121 and second 122 bleeder resistors. The first 121 and second 122 bleeder resistors form a voltage divider that in operation divides the supply voltage,

[0028] The power converter circuit 102 includes a low-voltage transistor 132 implementing a second semiconductor switching element of the driver circuit 100. The low-voltage transistor 132 is connected between ground potential and, via a transistor cross connection terminal 142 of the integrated circuit 102, the second end of the second bleeder resistor 122. In the present case, both the high-voltage transistor 131 and the low-voltage transistor 132 are field effect transistors e.g. of CMOS type in source-follower configuration. In alternative embodiments, the high-voltage 131 and low-voltage 132 transistors are bipolar transistors in emitter-follower configuration.

[0029] The integrated circuit 102 further comprises a differential amplifier 116 for controlling the high-voltage transistor 131, the output of the differential amplifier 116 being connected via a transistor control terminal 141 of the integrated circuit to an input of the high-voltage transistor 131, corresponding in the present case, where the high-voltage transistor 131 is implemented as a field effect transistor, to a gate terminal of the high-voltage transistor 131. An inverting first input of the differential amplifier 116 is connected via the transistor cross connection terminal 142 to the second end of the second bleeder resistor 122, while a non-inverting second input of the differential amplifier 116 is connected to a first output of a bleeder controller unit 105, implemented within the integrated circuit 102, for controlling the bleeding functionality of the driver circuit 100. A non-inverting third input of the differential amplifier 116 is connected with a second output of the bleeder controller unit 105 adapted for providing a fixed and stable reference voltage enabling weak bleeder action in which this reference voltage is reproduced across the weak bleeder resistor 122. A third output of the bleeder controller unit 105 is connected to an input of the low-voltage transistor 132, corresponding in the present case, where the low-voltage transistor 132 is implemented as a field effect transistor, to a gate terminal of the low-voltage transistor 132. A first input of the bleeder controller unit 105 is connected via a supply current sensing terminal 144 of the integrated circuit to the low-voltage output 191 of the rectifier 106. A second input of the bleeder controller unit 105 is connected via a supply voltage sensing terminal 143 of the integrated circuit 102 to connected first ends of first 151 and second 152 supply voltage sensing resistors, which form a voltage divider for deriving a sensing voltage from the supply voltage. The second end of the first supply voltage sensing resistor is connected to the high-voltage output 192 of the rectifier 106, while the second end of the second supply voltage sensing resistor is connected to ground potential 193. Further connections within the integrated circuit 102, such as between the bleeder controller unit 105 and the ground terminal 146 for providing the bleeder controller unit 105 with a ground 193 connection, or between the bleeder controller unit 105 and the general circuitry 104 or between the differential amplifier 116 and the general circuitry 104 for receiving the internal supply voltage of the integrated circuit 102, have been omitted in Fig. 1 for simplicity.

[0030] In the following, an exemplary method of operating the driver circuit 100 shall be described in accordance with the flow diagram given in Fig. 4. In an initial step 400, a dimmer providing a dimmed mains voltage by means of phase-cut circuitry is connected to the supply voltage terminals 114 of the driver circuit 100. Fig. 3A illustrates, in a diagram having a vertical voltage axis 302 and a horizontal time axis 300, the change over time 300 of a sinusoidal mains voltage 311 and a dimmed mains voltage 310 that the dimmer in a stable operational state supplies to the supply voltage terminals 114. After a first zero crossing 361 of the mains voltage, the mains voltage 311 begins to rise while the dimmed mains voltage 310 remains at zero potential. After a customer-adjustable phase interval 361, 370 has passed, the dimmed mains voltage 310 quickly rises to the level of the mains voltage 311. Until a following zero-crossing 362 of the mains voltage 311, the dimmed mains voltage 310 coincides with the sinusoidal waveform of the mains voltage 311. The same process is repeated for each half-wave of the mains voltage 311.

[0031] Between its high-potential 192 and low potential 191 outputs, the rectifier 106 provides a rectified dimmed mains voltage 312, which is illustrated in Fig. 3A. The rectified dimmed mains voltage 312 intermittently charges the storage capacitor 113 during phases where the rectified dimmed mains voltage 312 is higher than a stored voltage 314 between the ends of the storage capacitor 113, the diode 190 preventing the capacitor from being discharged during phases where the rectified dimmed mains voltage 312 is lower than the stored voltage 314. Fig. 3C illustrates along a vertical current axis 306 the change in time of the input current 316 of the driver circuit 100. The phases where the rectified dimmed mains voltage 312 is higher than the stored voltage at the storage capacitor 113 correspond to high-current phases 322 of the input current 316.

[0032] In step 408 as shown in Fig. 4, the controller unit 105, by sensing the potential at the connected first ends of the supply voltage sensing resistors 151, 152, detects a predefined low-voltage phase 321 during which the rectified dimmed mains voltage 312 is below a predefined voltage threshold 351. This will occur after the rectified dimmed mains voltage 312 crosses the level of the voltage threshold 351 from above, shortly before the next zero crossing 362 of the mains voltage 311. The voltage threshold 351 as shown in Fig. 3B is e.g. 1/10 or less of the peak voltage of the rectified dimmed mains voltage 312.

[0033] In step 410, upon detecting the low-voltage phase 321 in step 408, the bleeder controller unit 105 switches the low-voltage transistor 132 and, via the differential amplifier 116, the high-voltage transistor 131 to a conductive state. This causes the first bleeder resistor 121 to be connected between ground potential 193 and the high-voltage output 192 of the rectifier 106. Because initially in the low-voltage phase 321 the rectified dimmed mains voltage 312 is close to zero, only little energy is dissipated in the first bleeder resistor 121.

[0034] In step 412 the controller unit 105, by sensing the potential at the low-voltage output 191 of the rectifier 106, which corresponds to the voltage drop at the current sensing resistor 108, detects a predefined high-current phase 322 during which the input current 316 is not below a predefined current threshold 352. For particularly high reliability, the controller unit 105 may additionally sense the voltage at the connected first ends of the supply voltage sensing resistors 151, 152 in order to detect the high-current phase 322, e.g. by requiring both the rectified dimmed mains voltage 312 voltage to rise above the voltage threshold 351 and the input current 316 to rise above the current threshold 352 for the detection to take place. This will occur shortly after the customer-adjustable phase interval 361, 370 has passed, when the dimmed mains voltage 310 quickly rises to the level of the mains voltage 311 and begins to charge the storage capacitor 113. The current threshold 352 as shown in Fig. 3C is e.g. 1/10 or less of the peak input current 316.

[0035] In step 414, upon detecting the high-current phase in step 412, the controller unit 105, via the differential amplifier 116, switches the high-voltage transistor 131 to a non-conductive state. This causes all bleeding action to stop.

[0036] In step 404, by sensing by sensing the potential at the low-potential output 191 of the rectifier 106, detects a predefined low-current phase 323 during which the input current is below the predefined current threshold 352. This will occur shortly after the rectified dimmed mains voltage 312 begins to fall below the stored voltage 314 at the storage capacitor 113.

[0037] In step 416, upon detecting the low-current phase 323 in step 404, the controller 105 switches the low-voltage transistor 132 to a non-conductive state, and activates the differential amplifier 116 such that the differential amplifier 116 via the transistor cross connection terminal 142 of the integrated circuit 102 senses the voltage drop across the second bleeder resistor 122, and regulates the voltage drop by controlling the conductivity of the high-voltage transistor 121, to a predefined constant value, based on the sensing input. Afterwards, the method continues at step 408.

[0038] An exemplary implementation of the controller unit 105 is given in Fig. 2, which depicts an integrated circuit 102 such as used in the driver circuit 100 of Fig. 1. The controller unit 105 as shown comprises a first inverting Schmitt trigger 201 for sensing the input current of the driver circuit. The inputs of the first Schmitt trigger 201 are connected to the input current sensing terminal 144 and a first constant voltage source 211, which defines the current threshold 352 in form of a corresponding threshold potential at the input current sensing resistor 122. The output of the first Schmitt trigger 201 is connected via a logic inverter 203 to a first input of a first NAND gate 221. The output of the first NAND gate 221 is connected to the gate of the low-voltage transistor 132.

[0039] The controller unit 105 further comprises a second inverting Schmitt trigger 202 for sensing the rectified dimmed mains voltage 312. The inputs of the second Schmitt trigger 202 are connected to the supply voltage sensing terminal 143 and a second constant voltage source 212, which defines the voltage threshold 351 in form of a corresponding threshold potential at the connected first ends of the supply voltage sensing resistors 151, 152. The output of the second Schmitt trigger 202 is connected to a second input of the first NAND gate 221 and to a first input of a second NAND gate 222. The output of the second NAND gate 222 is connected to the non-inverting second input of the differential amplifier 116, the inverting first input of the differential amplifier 116 being connected to the transistor cross connection terminal 142 as described above. A second input of the second NAND gate 222 is connected to the output of the first Schmitt trigger 201. Furthermore, a third constant voltage source 213 of the controller unit 105 is connected to the non-inverting third input of the differential amplifier 116 for defining a desired voltage drop across the second bleeder resistor 122 as a regulation target during the low-current phase 323.

Claims

1. Driver circuit (100) for driving a lighting device (110) for being connected between a dimmed supply voltage (114) and said lighting device (110), the driver circuit (100) comprising:

    - a first bleeder resistor (121) having a first end connected to a high-voltage terminal (192) of the supply voltage (114);
    - a second bleeder resistor (122) having a first end connected to a low-voltage terminal (191) of the supply voltage (114);
    - a first semiconductor switching element (131) connected between the second ends of the first (121) and second (122) bleeder resistors; and
    - a second semiconductor switching element (132) connected between the second end of the second bleeder resistor (122) and the low-voltage terminal (191) of the supply voltage (114).

2. Driver circuit (100) according to claim 1, further comprising:

    - a voltage detector (151, 152, 202) for detecting whether the supply voltage (114) is below a predefined voltage threshold (351);
    - a current detector (108, 201) for detecting whether an input current of the driver circuit (100) is below a predefined current threshold (352); and
    - a controller (105, 116) for controlling the first (131) and second (132) semiconductor switching elements based on output of the voltage (151, 152, 202) and current (108, 201) detectors, the controller (105, 116) being arranged to regulate a voltage drop across the second bleeder resistor (122) when the supply voltage is not below the voltage threshold (351) and the input current is below the current threshold (352).

3. Driver circuit according to claim 2, the controller (105, 116) being arranged to switch the first semiconductor switching element (131) to a non-conductive state when the input current is not below the current threshold (352).

4. Driver circuit according to claim 2 or 3, the controller (105, 116) being arranged to switch the first (131) and second (132) semiconductor switching elements to a conductive state when the supply voltage is below the voltage threshold (351).

5. Driver circuit (100) according to any one of claims 2 to 4, wherein the controller (105, 116) comprises a differential amplifier (116), a first input of the differential amplifier (116) being connected to the second end of the second bleeder resistor (122).

6. Driver circuit (100) according to claim 5, wherein an output of the differential amplifier (116) is connected to an input of the first semiconductor switching element (131).

7. Driver circuit (100) according to any one of claims 2 to 6, wherein the current detector (108, 201) comprises:

    - a sensing resistor (108) for sensing the input current of the driver circuit (100); and
    - a first Schmitt trigger (201) for detecting a drop in the input current below said predefined current threshold (352).

8. Driver circuit (100) according to any one of claims 2 to 7, wherein the voltage detector (151, 152, 202) comprises:

    - a voltage divider (151, 152) for deriving a sensing voltage from the supply voltage (114); and
    - a second Schmitt trigger (202) for detecting a drop of the sensing voltage below said predefined voltage threshold (351).

9. Driver circuit (100) according to any one of claims 2 to 8, wherein the second semiconductor switching element (132) and the controller (105, 116) are combined in an integrated circuit (102).

10. Driver circuit (100) according to one of the preceding claims, wherein the first (131) and/or second (132) semiconductor switching elements comprise a transistor.

11. Lighting device (100, 110) comprising a lighting element (110) and a driver circuit (100) according to any one of the preceding claims, the driver circuit (100) being configured for driving the lighting element (110).

12. Lighting device (100, 110) according to claim 11, wherein the lighting element (110) comprises at least one light emitting diode (111), compact fluorescent lamp, cold cathode fluorescent lamp, or halogen lamp.

13. Method for operating a driver circuit (100) according

to any one of claims 1 to 12, the method comprising:

- detecting (404) a predefined low-current phase (323) of an input current of the driver circuit (100), the input current being below a predefined current threshold (352) and the supply voltage being not below a predefined voltage threshold (351) during the low-current phase (323);
- regulating (416) upon detecting (404) the low-current phase (323) a voltage drop across the second bleeder resistor (122) during the low-current phase (323).

14. Method according to claim 13, further comprising:

- detecting (408) a predefined low-voltage phase (321), the supply voltage being below the predefined voltage threshold (351) during the low-voltage phase (321);
- switching (410) upon detecting upon detecting (408) the low-voltage phase (321) the first (131) and second (132) semiconductor switching elements to a conductive state.

15. Method according to claim 13 or 14, further comprising:

- detecting (412) a predefined high-current phase (322), the input current being not below the predefined current threshold (352) during the high-current phase (322); and
- switching (414) upon detecting (412) the high-current phase (322) the first semiconductor switching element (131) to a non-conductive state.

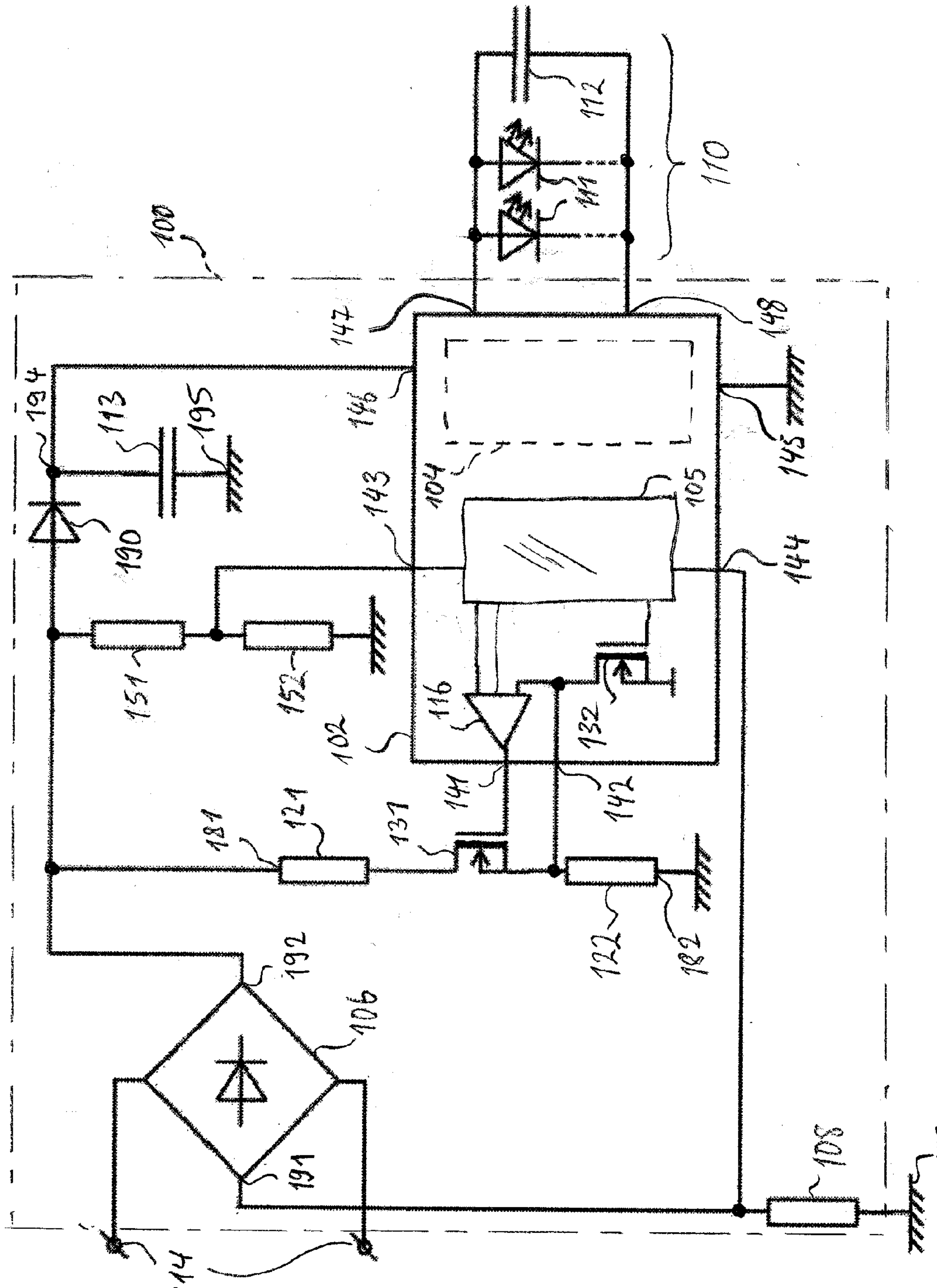
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Fig. 1

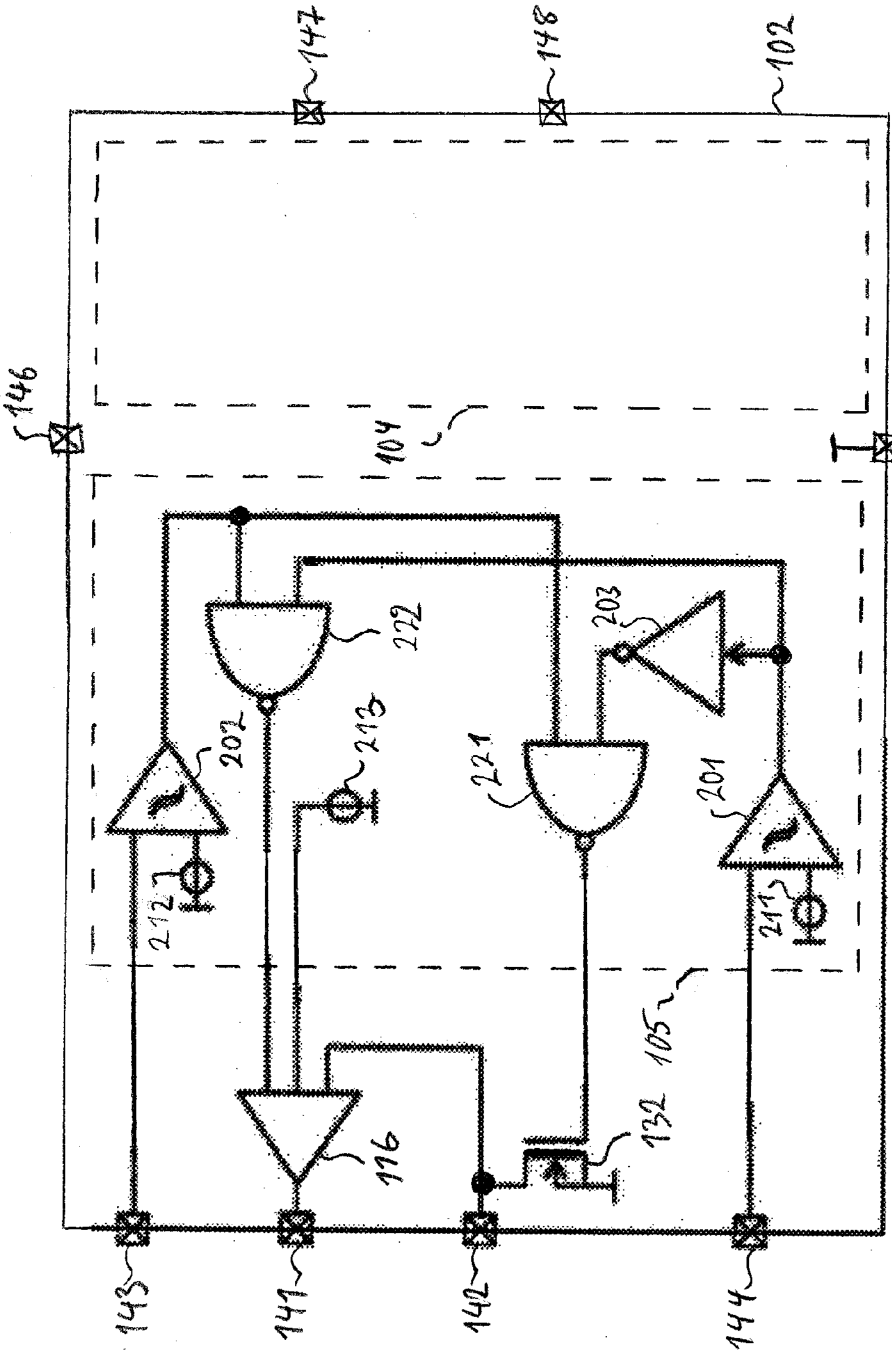
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Fig. 2

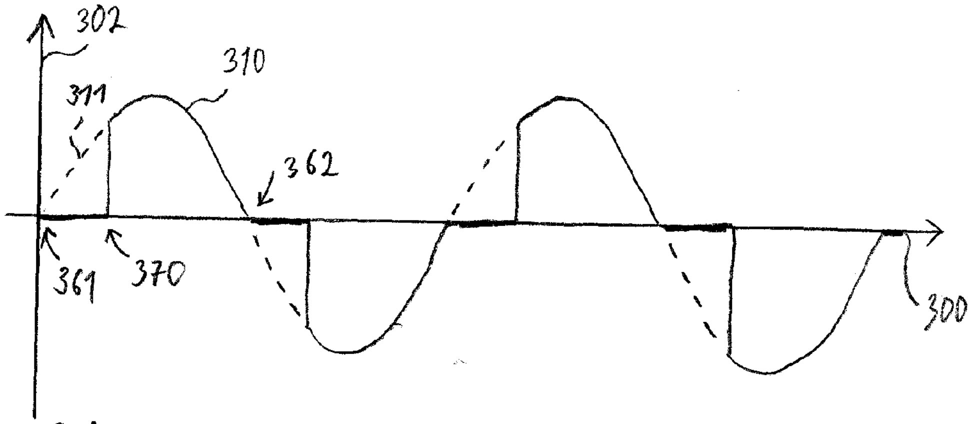

Fig. 3A

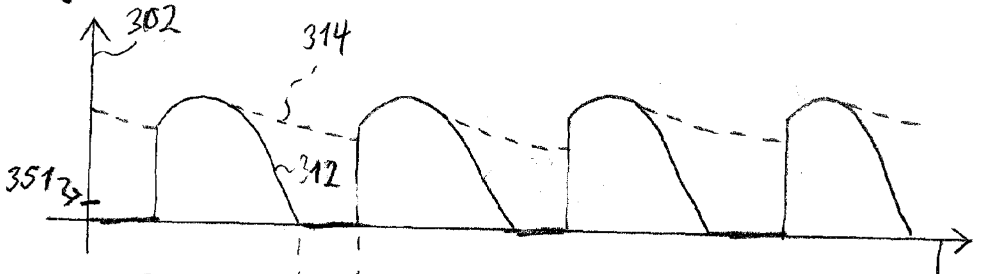

Fig. 3B

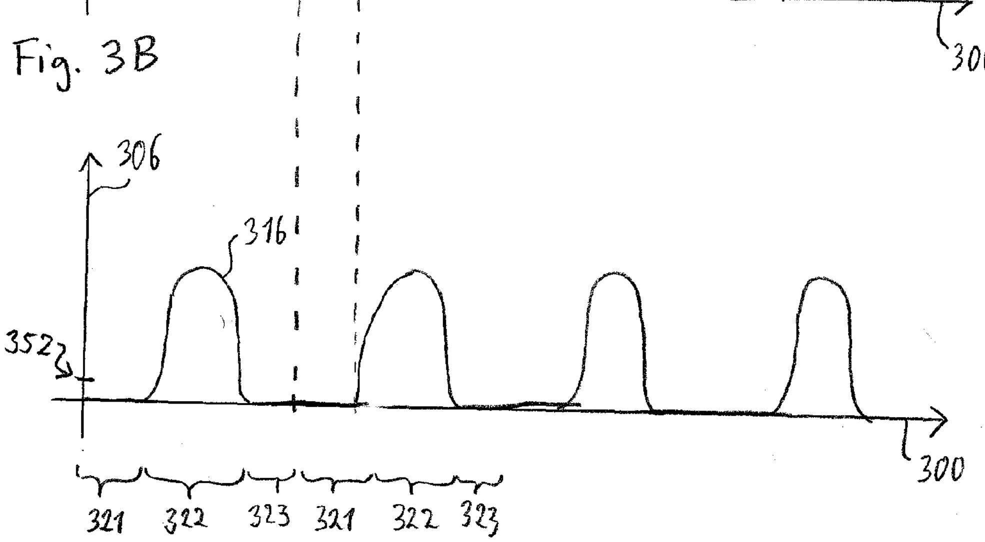

Fig. 3C

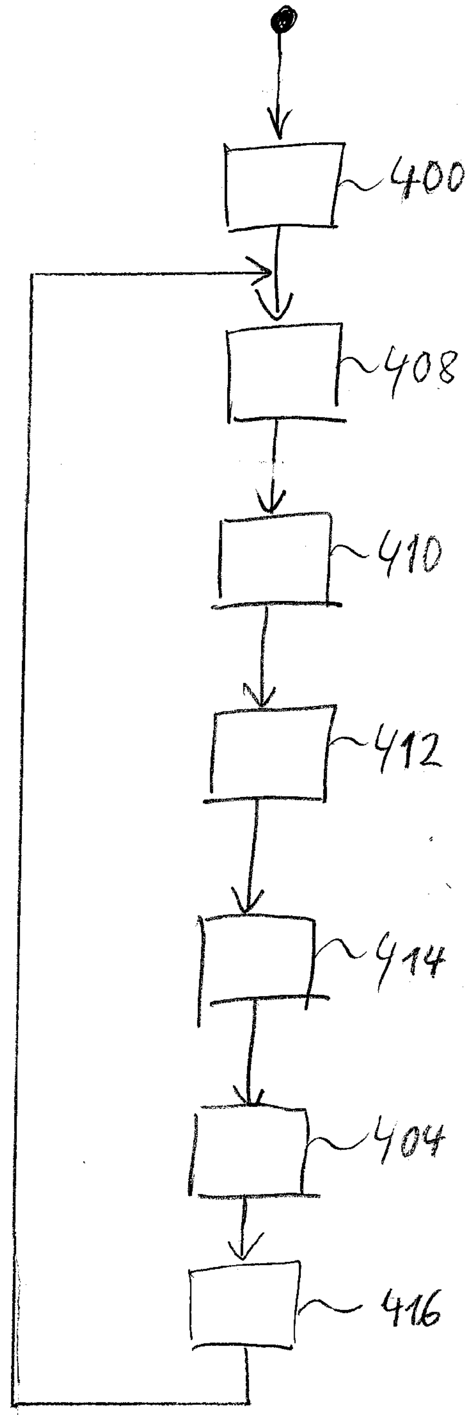

Fig. 4

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EUROPEAN SEARCH REPORT

Application Number
EP 10 15 8998

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
A,D	SSL2101 Product data sheet: "SMPC IC for dimmable LED lighting" 28 August 2009 (2009-08-28), NXP Semiconductors , Netherlands , XP002601664 , pages 1-22 * paragraph [08.5]; figures 1,5 *	1-15	INV. H05B33/08
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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
The Hague	22 September 2010	Albertsson, Gustav

CATEGORY OF CITED DOCUMENTS

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