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# (54) Driver module for driving LEDs

(57) The invention proposes a driver module (1) for driving LEDs,
wherein the driver module (1) comprises:
- a load path (4) comprising at least one LED string (6) with one or a plurality of LEDs (12, 13),
- a current source (7) connected in series with the load path (4) for generating a current for the load path (4), and
- a control module (8) for controlling the current for the load path (4) so that the shape of the current for the load path (4) matches the voltage (VA) applied to the load path (4).

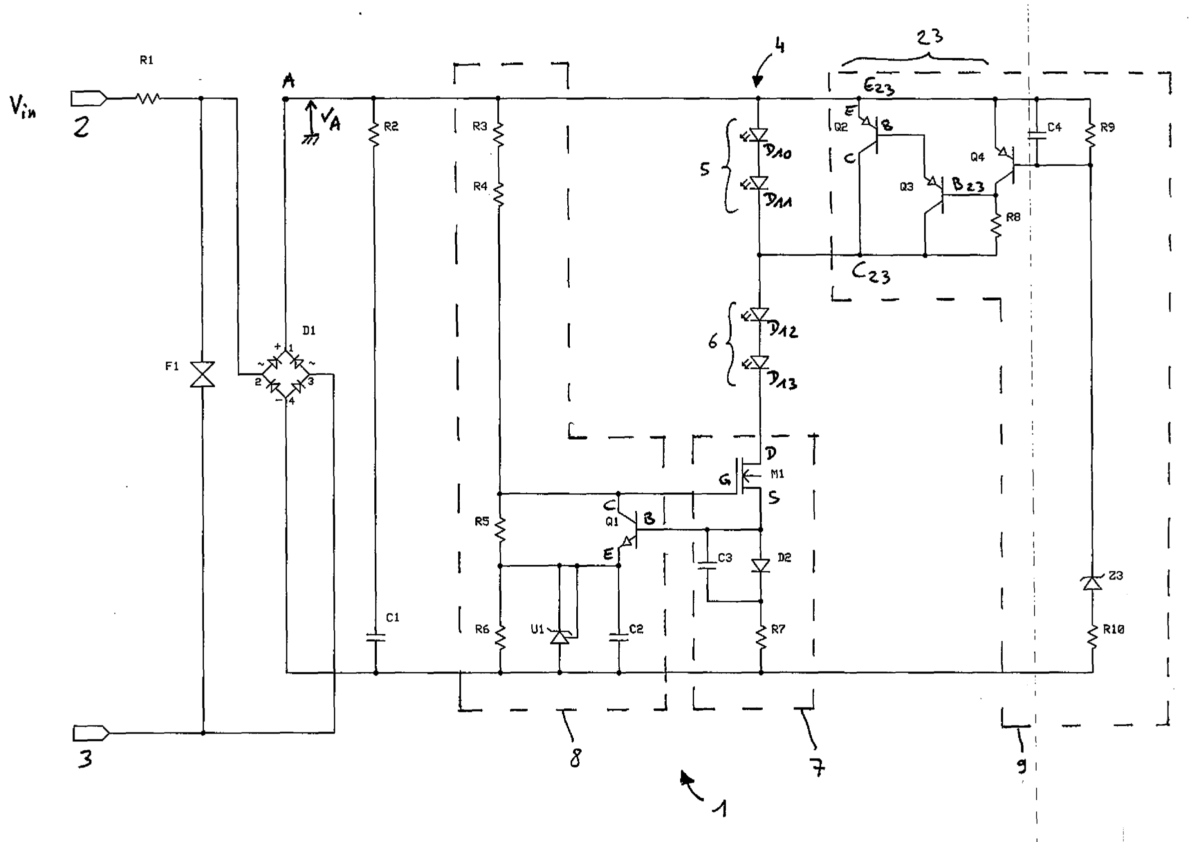


Fig. 1



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## Description

**[0001]** The invention is directed on a driver module for driving LEDs directly from an AC supply. 'Directly' has to be understood that there is no switch mode circuitry in this driver.

**[0002]** It is already known, e.g. from document WO 2013101759 A1, to drive a string of LEDs directly from AC voltage. According to this document the string of LEDS is divided in several sub-groups. Raising amplitude of the sine wave of the mains AC voltage implies that more and more stages of LEDs are switched to be operative. At the same time, each time an additional group of the series connection of LEDs is switched on, a current source with increasing power is switched on. Thus, not only an increasing number of LEDs will be switched on, but also stepwise the current through the LED string will increase in order to roughly match the shape of the sine-wave of the AC voltage.

**[0003]** Document US 2003/164809 A1 discloses a circuit for a plurality of LEDs. The circuit comprises a serial path comprising the LEDs and a constant current sink. In addition to this constant current sink, further switchable constant current devices are connected with the serial path. Depending on the input voltage, some of the further switchable constant current devices may be switched. Thereby, it is disadvantageous that the circuit comprises several current sources and that current sources have to be switched on and off.

**[0004]** The present invention proposes an improved solution for driving LEDs.

**[0005]** The invention now has a new approach to make the current flowing through the LED string match the shape of the AC sine-wave of the mains voltage.

**[0006]** According to a first aspect of the invention, a driver module for driving LEDs is proposed. The driver module comprises a load path comprising at least one LED string with one or a plurality of LEDs. The driver module comprises a current source connected in series with the load path for generating a current for the load path. The driver module comprises a control module for controlling the current for the load path so that the shape of the current for the load path matches the voltage applied to the load path.

**[0007]** According to a further aspect of the invention, a method for driving LEDs is proposed. The method comprising the following steps of supplying an alternating voltage such as a mains voltage, and rectifying the alternating voltage. The rectified voltage is applied to a load path comprising at least one LED string with one or a plurality of LEDs. A current for the load path is generated. The current for the load path is controlled so that the shape of the current for the load path matches the voltage applied to the load path.

**[0008]** In other words, the shape of the current through the load path, i.e. through the at least one LED string, and through the current source corresponds to the shape of the voltage that is across both the current source and the load path. They have the same shape.

**[0009]** This means that the current source is programmed to control the current through the LED string to develop totally the shape of the input AC sine-wave.

**[0010]** Advantageously, the voltage applied to the load path corresponds to the voltage across the load path and the current source.

**[0011]** Advantageously, the current source comprises a transistor operated in the linear mode. Advantageously, the control module is connected to a control pin and a further pin of the transistor to control the current for the load path.

**[0012]** In case the transistor is a field-effect transistor (FET) or a MOSFET, the control pin corresponds to the gate of the transistor and the further pin corresponds to the source.

**[0013]** Advantageously, the current source comprises a transistor operated in the linear mode for adapting the current for the load path.

**[0014]** This means that advantageously the current source does not comprise a switching stage for adapting the current through the LEDs.

**[0015]** Advantageously, the current source comprises a resistor traversed by the current for the load path. Advantageously, the control module comprises a voltage divider for generating an output voltage that is proportional to the voltage applied to the load path. The resistor and the voltage divider are coupled so that the output voltage of the voltage divider has the same time-dependency as the current through the resistor.

**[0016]** The resistor mentioned here is advantageously connected in series with the transistor.

**[0017]** The resistor and the voltage divider are coupled in such a way that the output voltage of said voltage divider is connected to the emitter of a transistor of the control module, and that the base of this transistor is connected to the source of the transistor of the current source.

**[0018]** Advantageously, the control module comprises a voltage divider for generating a voltage proportional to the voltage applied to the load path. Advantageously, the control module is adapted to control the current for the load path on the basis of the generated voltage.

**[0019]** Advantageously, the driver module comprises input terminals for receiving an alternating voltage such as a mains voltage, and a rectifier for rectifying the received alternating voltage. Advantageously, the rectified alternating voltage is the voltage applied to the load path.

**[0020]** Advantageously, the load path comprises a further LED string with one or a plurality of LEDs, the further LED string being connected in series with the LED string. Advantageously, a bypass module is connected in parallel to the further LED string and is adapted to bypass the further LED string.

**[0021]** Advantageously, the bypass module is adapted to bypass the further LED string in case the voltage across the further LED string is not sufficient to switch it on.

**[0022]** Advantageously, in case the voltage applied to the load path is below a given threshold, the bypass module is adapted to bypass the further LED string such that the current for the load path flows through the LED string but not through the further LED string.

**[0023]** Advantageously, in case the voltage applied to the load path is above said given threshold, the bypass module does not bypass the further LED string such that the current for the load path flows through the LED string and through the further LED string.

**[0024]** Advantageously, the LEDs of the LED string and of the further LED string are respectively arranged in series.

**[0025]** This means that the LEDs of the LED string are connected in series, as well as the LEDs of the LED string.

**[0026]** To summarize, the invention proposes to use a current source which is programmed to control the current through the LED string to develop totally the shape of the AC sine-wave.

**[0027]** In an embodiment shown in the invention report, a transistor operated in the linear mode is used to control the current through the LED string.

**[0028]** In principle, a single non-switch of LEDs can be used.

**[0029]** In a preferred embodiment, a plurality (at least two) groups of LED strings are used in a switched mode.

**[0030]** Thus, when the AC voltage is above a certain threshold, the upper LED string (comprised of two LEDs in the example) is switched operative (the shunting transistor is switched off), such that the current flows through all LEDs of the string. Below the mentioned voltage, one of the groups of LEDs is bypassed and the current will only flow through the remaining LEDs.

**[0031]** The advantage of the invention is that only a single current source is required, which is programmed in the example by a voltage divider.

**[0032]** A further advantage of the LED driver according to the invention is that it is easily dimmable when using usual dimmers as for example phase cut dimmers.

**[0033]** A Zener diode is present to limit the current to a maximum value.

**[0034]** There is no switched current source in this LED driver, but it may have switching stages for subgroups of the LED string.

**[0035]** Further features, advantages and objects of the present invention will become evident from the following detailed description of preferred embodiments of the invention, when taken in conjunction with the figure of the enclosed drawing.

FIG. 1 illustrates a schematic diagram of a driver module 1 for driving LEDs according to the present invention.

FIG. 2 illustrates a schematic diagram of a driver module 1 for driving LEDs according to another embodiment of the present invention.

**[0036]** The driver module 1 for driving LEDs D10, D11, D12, D13 shown in Fig. 1 is supplied with an input voltage Vin in the form of an alternating voltage such as a mains voltage. The alternating voltage is applied between a first input terminal 2 and a second input terminal 3 acting as reference terminal or neutral.

**[0037]** The first input with the higher electric potential is connected to a first terminal of a resistor R1. A diode F1, e.g. a transient-voltage-suppression (TVS) diode, is provided between the second terminal of the resistor R1 and the second input terminal 3. This optional diode F1 is used for protecting the driver module 1 e.g. from voltage spikes.

**[0038]** The input voltage Vin is applied to a rectifier for converting the alternating voltage (AC) to a rectified voltage (DC). The embodiment of Fig. 1 preferably comprises a bridge rectifier D1 comprising four diodes in bridge configuration. The output of the bridge rectifier D1 is a full-wave rectified voltage V provided between a positive terminal + and a negative terminal - of the rectifier D1. The negative terminal - corresponds to ground, while the positive terminal + at node A represents voltage VA.

**[0039]** The preferably rectified input voltage VA is applied to a resistor R2 and a capacitor C1 that are connected in series between node A and ground.

**[0040]** An advantage of the LED driver according to the present invention is that it is easily dimmable when using usual dimmers as for example phase cut dimmers, wherein the voltage generated by such a phase cut dimmer may be applied to the input terminal 2, 3 of the driver module.

**[0041]** The elements R1, R2 and C1 are present in order to enable a dimming operation using a phase cut dimmer as they form a passive bleeding circuit. Furthermore, the mentioned elements R1, R2 and C1 represent damping elements avoiding ringing effects - in view of capacities provided on the dimmer - caused when operated with usual dimmers.

**[0042]** A load path 4 comprising two LED sets or LED strings 5, 6 is connected to node A, i.e. to the voltage VA. A first LED set 5 is thereby connected in series with a second LED set 6 within the load path 4. Each LED set 5, 6 comprises at least one LED, preferably a plurality of LEDs connected in series and/or in parallel. In the particular embodiment of Fig. 1, the two LEDs 10, 11 of the first LED set 5 schematically represent a plurality of LEDs coupled in series. Also, the two LEDs 12, 13 schematically represent a series of coupled LEDs for the second LED set 6. The anode of the LEDs is connected towards node A. For the particular LED sets of Fig. 1, this means that the anode of the first LED D10 of the first LED set 5 is coupled to node A and voltage VA.

**[0043]** The driver module 1 now comprises a current source 7 for controlling the current flowing through the LEDs 10, 11, 12, 13 and through the LED sets 5, 6. The current source 7 is advantageously operated so that the current through the LEDs follows the shape of the sine-wave of the rectified voltage VA. The current source 7 is set up for driving a non-constant current through the load path 4 and thus through the LED sets 5, 6.

**[0044]** The current source 7 comprises a switch in the form of a transistor M1 for controlling the current through the LEDs. Said transistor M1 is connected in series with the LED sets 5, 6, and particularly with the second LED set 6. Said transistor M1 is implemented as a power transistor. In the embodiment of Fig. 1, the transistor M1 is particularly a field-effect transistor (FET), and preferably an N-channel metal-oxide-semiconductor field effect transistor (MOSFET).

**[0045]** The drain of the transistor M1 is connected to the cathode of the last serial connected LED D13 of the second LED set 6. The source of the transistor M1 is coupled to a parallel arrangement of a diode D2 and of a capacitor C3, which parallel arrangement is in turn coupled to ground via a resistor R7.

**[0046]** To control the current through the LEDs, the transistor M1 is advantageously operated in the linear mode i.e. in the ohmic mode. In this linear mode, the transistor M1 is turned on and the gate-source voltage of the transistor M1 is above the threshold voltage Vth. The characteristic of drain current versus drain-to-source voltage is nearly linear for e.g. small values of the drain-source voltage.

**[0047]** The current source 7 and the transistor M1 are controlled by a control module 8. The control module 8 comprises a switch and particularly a transistor Q1 that is preferably a bipolar junction transistor of the NPN-type. Said transistor Q1 is coupled to the transistor M1, in that e.g. its collector C is connected to the gate G of transistor M1 while its base B is connected to the source S of transistor M1.

**[0048]** The collector of transistor Q1 is further coupled to node A via a series arrangement of two resistors R3, R4. The collector C and the emitter E of transistor Q1 are linked to each other via a resistor R5. Further on, a resistor R6, a tunable Zener diode U1 and a capacitor C2 are respectively connected in parallel between ground and the emitter E of transistor Q1.

**[0049]** The current source 7 is controlled or programmed by the control module 8, and preferably by a voltage divider. Such a voltage divider can be formed on the one hand by the serial arrangement of resistors R3, R4 and on the other hand by the serial arrangement of resistors R5, R6. The output of the voltage divider - i.e. the voltage across the resistors R5, R6 - is applied to the gate of the power transistor M1 of the current source 7 and to the collector of the transistor Q1.

**[0050]** The control module 8, i.e. the programming circuitry for the current source 7, is made such that the voltage across the resistor R7 equals the voltage across the resistor R6. Advantageously, the current through the resistor R7 will then have the same time-dependency as the current through the resistor R6.

**[0051]** A further voltage divider is thus defined by the resistors R3, R4, R5 on the one hand and by the resistor R6 on the other hand. The output of this voltage divider - i.e. the voltage across the resistors R6 - is applied to the emitter of the transistor Q1, and sets what the drain current of the power transistor M1 will be.

**[0052]** Thereby, the base-emitter voltage of the transistor Q1 of the control unit 8 corresponds, i.e. is approximately equal, to the voltage across the diode D2 of the current source 7. Thus, the voltage across the resistor R7 corresponds to the voltage across the resistor R6.

**[0053]** The tunable Zener diode U1 can e.g. be a standard component such as LM431 - Adjustable Precision Zener Shunt Regulator - or TL431, commercially available from e.g. Texas Instruments. The anode of the tunable Zener diode is connected to ground, while its cathode and a reference terminal of the tunable Zener diode U1 are connected to the emitter E of transistor Q1. Advantageously, the tunable Zener diode U1 sets a voltage reference. The diode U1 is present to limit the current to a maximum allowable value.

**[0054]** According to the present invention, a bypass module 9 is connected in parallel to the first set of LEDs 5 so that the LED set 5 can be bypassed depending on the voltage VA applied to the anode of the LED set 5 and to the bypass module 9.

**[0055]** The bypass module 9 comprises two transistors Q2, Q3 arranged according to a Darlington circuit 23. The transistors Q2, Q3 are e.g. in the form of bipolar junction transistors, and preferably of the PNP-type. Alternatively, the transistors Q2, Q3 can also be of the NPN-type, or they can be of opposite type, one NPN and one PNP, and arranged according to a Sziklai configuration. Both transistors Q2, Q3 have a common collector in that their respective collectors are connected together. The transistors are further on coupled such that the emitter current of the transistor Q3 becomes the base current of the transistor Q2. The transistor Q2 is connected as an emitter follower and the transistor Q3 as a common emitter amplifier.

**[0056]** The rectified voltage VA is applied to the emitter E23 of the Darlington 23. The collector C23 of the Darlington is connected to the cathode of the LED set 5, i.e. at the joining node between both LED sets 5, 6. In fact, the emitter E23 and collector C23 of the Darlington 23 are connected in parallel to the LED set 5, such that the bypass module 9 can indeed bypass the LED set 5 if the Darlington 23 is switched on.

**[0057]** A further transistor Q4, e.g. a bipolar junction transistor preferably of the PNP-type, is coupled to the Darlington 23, in that their respective emitters are connected and in that the base B23 of the Darlington is connected to the collector of the transistor Q4. A resistor R8 is also connected between base B23 and collector C23 of the Darlington. A parallel RC circuit composed of capacitor C4 and resistor R9 is connected between emitter and base of the transistor Q4. The base of the transistor Q4 is further coupled to ground via a serial arrangement of a Zener diode Z3 and of a resistor R10.

**[0058]** According to the present invention, the bypass module 9 is adapted to bypass the LED set 5 when the rectified AC voltage VA is below a given threshold. On the contrary, the bypass module 9 is switched off if said rectified AC voltage VA is above said given threshold. Above this threshold, the shunting transistor 23 (Darlington circuit 23) is switched off so that current will flow through the LED set 5. The switching of the bypass module may be controlled through the Zener voltage of the Zener diode Z3 which may be for instance 270 Volt.

**[0059]** The reason for switching operative the LED set 5 above said given threshold is the efficiency of the driver module. Above said threshold the voltage VA applied to the load path 4 is indeed sufficient for lighting said LED set 5. On the other hand, if the applied voltage VA is too low, i.e. below said threshold, the voltage across both LED sets 5, 6 will not be sufficient to switch on both LED sets 5, 6

**[0060]** FIG. 2 illustrates a schematic diagram of a driver module 1 for driving LEDs according to another embodiment of the the invention. The circuit of Fig. 2 is similar to the circuit of Fig. 1. The difference is that the current source 7 with the transistor M1 and the control module 8 is replaced by resistors R61 and R71. The resistors R61 and R71 act as ballasting resistors and limit the current through the LED. The resistor R61 is only switched in series to the LED set 6 when the Darlington circuit 23 is switched on and the LED set 5 is bypassed.

**[0061]** The invention is not limited to two LED sets 5, 6. E.g. the driver module can comprise a third LED set (not shown) comprised in the load path 4 in series with the two LED sets 5, 6. Also, a second bypass module (not shown) can be provided in parallel to the third LED set. The bypass module 9 connected to the LED set 5, and the second bypass module connected to the third LED set are then configured in such a way that the LED set 5 and the third LED set are switched operative at different threshold of the rectified AC voltage. For a low value of the AC voltage only the LED set 6 will be switched on, the two other LED sets being bypassed. For a higher value, both LED sets 5, 6 will be on, while only the third LED set will be bypassed. For an even higher value of the AC voltage, all three LED sets will be switched on, such that the current will flow through the all three LED sets and the overall light output can be increased.

**[0062]** Advantageously, there is no switched current source in the LED driver of the invention. A switch may however be used in a bypass module coupled to a subgroup of the LEDs.

## Claims

**1.** Driver module (1) for driving LEDs, wherein the driver module (1) comprises:

- a load path (4) comprising at least one LED string (6) with one or a plurality of LEDs (12, 13),
- a current source (7) connected in series with the load path (4) for generating a current for the load path (4), and
- a control module (8) for controlling the current for the load path (4) so that the shape of the current for the load path (4) matches the voltage (VA) applied to the load path (4).

**2.** Driver module according to claim 1, wherein the voltage (VA) applied to the load path (4) corresponds to the voltage (VA) across the load path (4) and the current source (7).

**3.** Driver module according to any of the preceding claims, wherein the current source (7) comprises a transistor (M1) operated in the linear mode, and the control module (8) is connected to a control pin (G) and a further pin (S) of the transistor (M1) to control the current for the load path (4).

**4.** Driver module according to any of the preceding claims, wherein the current source (7) comprises a transistor (M1) operated in the linear mode for adapting the current for the load path.

**5.** Driver module according to any of the preceding claims, wherein the current source (7) comprises a resistor (R7) traversed by the current for the load path (4), and the control module (8) comprises a voltage divider (R3-R4-R5, R6) for generating an output voltage (VR6) that is proportional to the voltage (VA) applied to the load path (4), wherein the resistor (R7) and the voltage divider (R3-R4-R5, R6) are coupled so that the output voltage (VR6) has the same time-dependency as the current through the resistor (R7).

**6.** Driver module according to any of the preceding claims, wherein the control module (8) comprises a voltage divider (R3-R4, R5-R6) for generating a voltage proportional to the voltage (VA) applied to the load path (4), and the control module (8) is adapted to control the current for the load path (4) on the basis of the generated voltage.

**7.** Driver module according to any of the preceding claims, the driver module comprising

- input terminals (2, 3) for receiving an alternating voltage (Vin) such as a mains voltage, and
- a rectifier (D1) for rectifying the received alternating voltage,

wherein the rectified alternating voltage is the voltage (VA) applied to the load path (4).

**8.** Driver module according to any of the preceding claims,
wherein the load path (4) comprises a further LED string (5) with one or a plurality of LEDs (10, 11), the further LED string (5) being connected in series with the LED string (6), and
a bypass module (9) is connected in parallel to the further LED string (6) and is adapted to bypass the further LED string (6).

**9.** Driver module according to claim 8,
wherein the bypass module (9) is adapted to bypass the further LED string (6) in case the voltage across the further LED string (6) is not sufficient to switch it on.

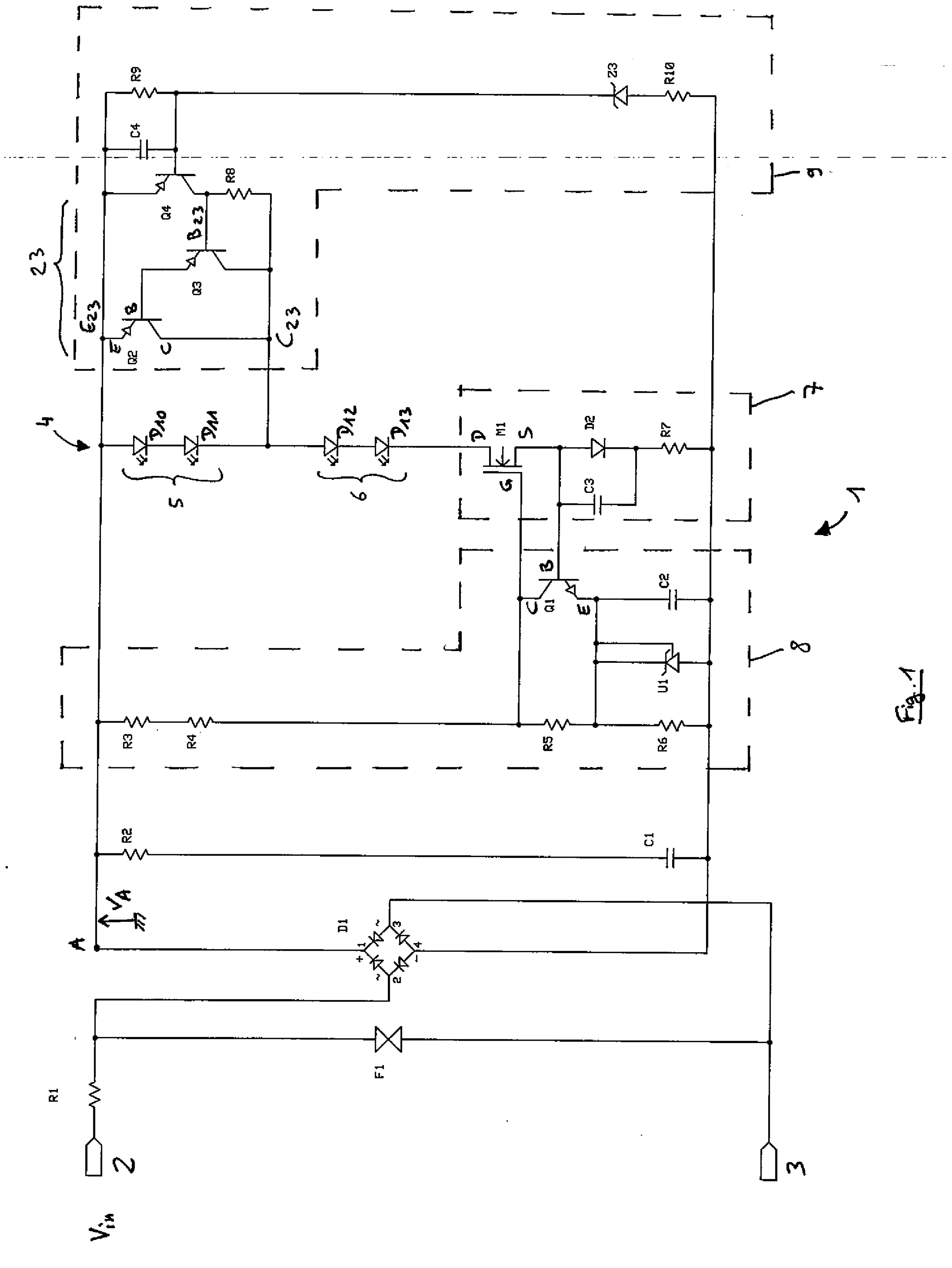
**10.** Driver module according to claim 8 or 9,
wherein, in case the voltage (VA) applied to the load path (4) is below a given threshold, the bypass module (9) is adapted to bypass the further LED string (6) such that the current for the load path (4) flows through the LED string (6) but not through the further LED string (5).

**11.** Driver module according to claim 10,
wherein, in case the voltage (VA) applied to the load path (4) is above said given threshold, the bypass module (9) does not bypass the further LED string (6) such that the current for the load path (4) flows through the LED string (6) and through the further LED string (5).

**12.** Driver module according to any of the preceding claims,
wherein the LEDs (D12, D13) of the LED string (6) and of the further LED string (6) are respectively arranged in series.

**13.** Method for driving LEDs,
the method comprising the following steps:

- supplying an alternating voltage (Vin) such as a mains voltage,
- rectifying the alternating voltage,
- applying the rectified voltage to a load path (4) comprising at least one LED string (6) with one or a plurality of LEDs (12, 13),
- generating a current for the load path (4), and
- controlling the current for the load path (4) so that the shape of the current for the load path (4) matches the voltage (VA) applied to the load path (4).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Q3
Q4
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Z3
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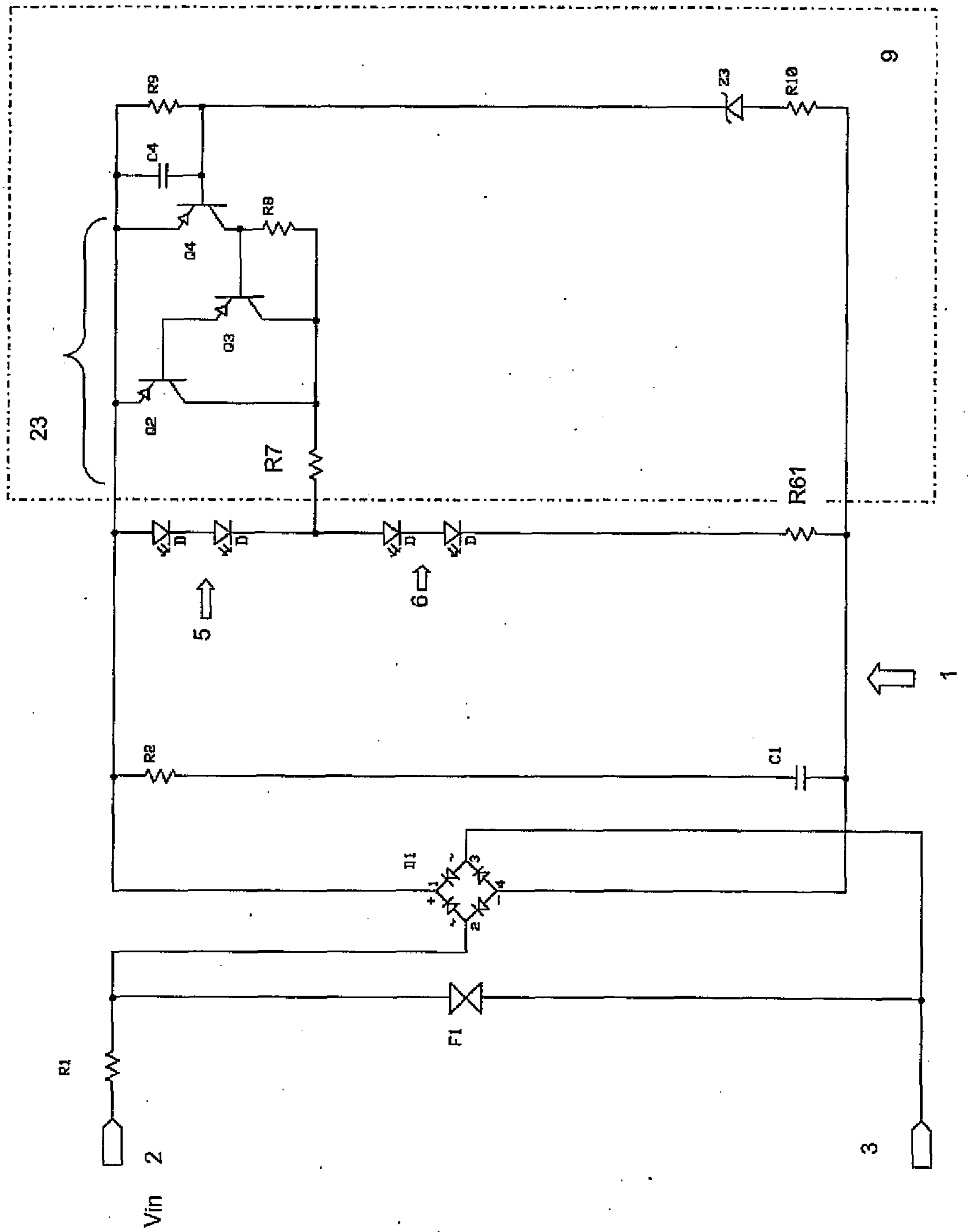
Fig. 1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# EUROPEAN SEARCH REPORT

Application Number
EP 13 19 3856

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The present search report has been drawn up for all claims

1

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CATEGORY OF CITED DOCUMENTS

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## ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 13 19 3856

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## REFERENCES CITED IN THE DESCRIPTION

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### Patent documents cited in the description


- WO 2013101759 A1 **[0002]**
- US 2003164809 A1 **[0003]**