(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
19 November 2015 (19.11.2015)

(10) International Publication Number
WO 2015/174877 A2

(51) International Patent Classification: Not classified

(21) International Application Number: PCT/RO2015/000012

(22) International Filing Date: 12 May 2015 (12.05.2015)

(25) Filing Language: ?ro:en?

(26) Publication Language: English

(30) Priority Data:
a2014 00368 15 May 2014 (15.05.2014) RO
a2015 00328 11 May 2015 (11.05.2015) RO

(72) Inventor; and
(71) Applicant : **RUS, Adrian Ioan** [RO/RO]; Strada Fermel 17, Sat Saftica, Balotesti, Jud ILFOV (RO).

(74) Agent: **FIERASCU, Cosmina**; ROMINVENT S.A., 35, Ermil Pangratti Street, Sector 1, 011882 Bucharest (RO).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:

— *of inventorship (Rule 4.17(iv))*

Published:

— *without international search report and to be republished upon receipt of that report (Rule 48.2(g))*

WO 2015/174877 A2

(54) Title: DIRECT AC LED DRIVER FLICKER INDEX REDUCTION CIRCUIT AND METHOD

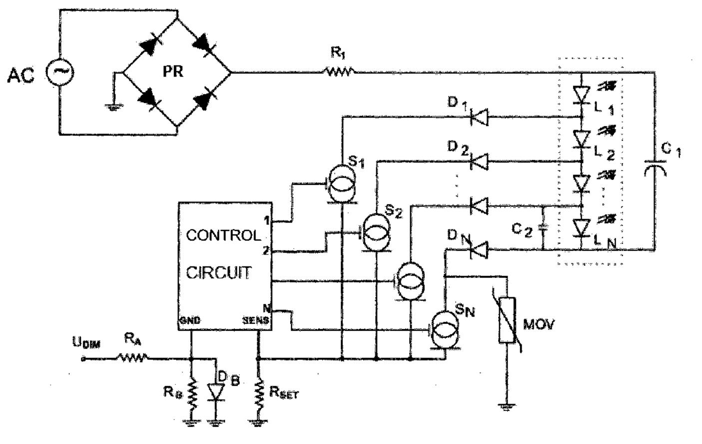

Fig. 11 The generalized electric diagram of the circuit according to the invention for reducing the flicker index, for N segments – variant with thermal stabilization

(57) Abstract: The present invention relates to a method of reducing the flicker index of a constant current direct AC LED driver, comprising the step of flowing a current through the segments (Li, L2,..., LN) of a LED string, when the power grid voltage value is smaller than the voltage drop on the string made of the segments (L-i, L2 LN), the flowing current equaling the discharge current of a capacitor (Ci) set in parallel with the string made of the segments (L-i, L2 LN), one lead of the capacitor (C-i) being connected to the anode of the first LED of the first segment (Li), and the other lead of the capacitor (C-i) being connected to the cathode of the last LED of the last segment (LN). The invention also relates to circuits associated to the above mentioned method.

DIRECT AC LED DRIVER FLICKER INDEX REDUCTION CIRCUIT AND METHOD

The present invention refers to circuit variants and to a method for reducing the flicker index of the LED light engines supplied directly from the public AC power grid at 230V, the so called „constant current direct AC drivers", or shortly „direct AC drivers".

Direct AC drivers experience an accelerated advancement, in 2014 being commercially available more than 20 specialized integrated circuits. Specific to direct AC integrated circuits is that they optimize only the electrical efficiency and the power factor; the direct result of this optimization strategy is that all the commercially available solutions exhibit a time interval between 2.5 and 3.5 ms long during which the LEDs are not lighting, as shown in Figure 1, i.e. they exhibit a flicker index greater than 0.34, the reference profile for calculating the flicker index being indicated in Figure 2.

In fact, the driver mediates between two processes coupled in series and characterized by different dynamic parameters, as following: the power is sunk from the power grid at a rate as close as possible to the sine function, and is supplied to the LEDs at a rate as constant as possible. The „lean production" theory of industrial processes developed by global manufacturers like Toyota, Bosch, etc., indicates the solution for solving the conflicts generated by this type of series coupled processes, but characterized by different dynamic parameters, namely: the decoupling of the processes.

The decoupling of the processes is done by using an accumulator, in which the first process supplies power at its own rate, and the second process sunk power, at a different rate than that of the first process. In Figure 3 the two processes are shown coupled in series and having different rates.

In order to balance the different power sink rates from the power grid, respectively the power supply rates to the LEDs, the only known solution is the one developed by Texas Instruments – http://www.ti.com/lit/ug/slvu965a/slvu965a.pdf. The solution implies the setting of electrolytic capacitors having the values of 33uF/100V, 68uF/50V and 120uF/25V respectively, in parallel of each of the 3 LED segments of a 10W module. The result of embedding these 3 electrolytic capacitors as energy accumulators is the reduction of the flicker index from 0.34 to approximately 0.12 and the reduction of the power factor from 0.98 to 0.96 over the whole range of grid voltage variation.

The technical problem solved by the present invention is the significant reduction (10 times approximately) of the flicker index of the LED modules supplied directly from the public power grid by means of direct AC drivers, with no impact on the power factor.

The method according to the invention, to reduce the flicker index of a constant current direct AC LED driver, comprises the step of flowing a current through the segments of a LED string, when the power grid voltage value is smaller than the voltage drop on the string made of segments, the flowing current equaling the discharge current of a capacitor set in parallel with the string made of segments, one lead of the capacitor being connected to the anode of the first LED of the first segment and the other lead of the capacitor being connected to the cathode of the last LED of the last segment.

The method according to the invention, as well as the circuit associated to the method, have the following advantages:

- Approximately 10 times reduction of the flicker index compared with classical direct AC drivers ;
- The use of a single capacitor having a moderate capacitance;
- The power factor of the direct AC driver is not altered;
- The efficiency of the direct AC driver is not altered;
- In case the power accumulative capacitor wears out and its capacitance reduces, the direct AC driver does not cease its operation and continues to function with a progressively increasing flicker index, up to the initial value reached without the capacitor.

The method according to the invention will be described next, as well as some embodiments of lighting circuits with LEDs associated to said method, in compliance with the drawings that illustrate:

Fig. 1 - time intervals during which the classic direct AC solutions do not light;
Fig. 2 - the reference profile defining the flicker index;

Fig. 3 - the decoupling principle;

Fig. 4 - the general electric diagram of a direct AC driver with 4 segments, compliant to the prior art;

Fig. 5 - the electric diagram of a circuit as according to the invention, in a first embodiment, with 4 LED segments;

Fig. 6 - the profile of the light emitted by the circuit shown in Fig. 5;

Fig. 7 - the profile of the current passing through the last segment L_N;

Fig. 8 - the electric diagram of the circuit as according to the invention, in a second embodiment, with an arbitrary N number of LED segments;

Fig. 9 - the electric diagram of the circuit as according to the invention, in a third embodiment, with an arbitrary N number of LED segments;

Fig. 10 - electric diagram of the circuit as according to the invention, in a fourth embodiment, with an arbitrary N number of LED segments;

Fig. 11 - electric diagram of the circuit as according to the invention, in a fifth embodiment, with an arbitrary N number of LED segments.

Figure 3 briefly presents the known principle of decoupling the power sunk from the grid, by the power supplied to the LEDs. The decoupling is done by an accumulator, wherein the first process is supplying energy with its own rate, different than the rate of the second process, which is sinking energy, where I_{sunk} is the current sunk from the grid, and i_{LED} is the current flowing through the LEDs.

In Figure 4 it is shown the known typical/classical direct AC LED driver schematic diagram, with 4 LED segments. Depending on the instantaneous value of the power grid voltage, the direct AC driver is sequentially coupling to the taps of the LED series a number of constant current sources so that the current sunk from the power grid by the circuit exhibits a stepped profile, as shown in Figure 1. The current flowing through LEDs is identical to the current sunk from the power grid, i.e. it also exhibits a stepped profile, the light emitted by the series of LEDs being therefore non-constant.

According to the invention, the LED direct AC flicker index reducing method comprises the step of flowing a current through the segments L_1, L_2,..., L_N of a LED string, when the power grid voltage value is smaller than the voltage drop on the string made of the segments L_1, L_2,..., L_N, the flowing current equaling the discharge current of a capacitor C_1 set in parallel with the string made of the segments L_1, L_2,...,

L_N, one lead of the capacitor C_1 being connected to the anode of the first LED of the first segment L_1, and the other lead of the capacitor C_1 being connected to the cathode of the last LED of the last segment L_N.

In figures 5, 8, 9, 10 and 11 are shown the electric diagrams of different embodiments of circuits associated with the method.

The circuit according to the invention as shown in Figure 5 is a particular case of the circuit shown in figure 8, wherein N=4, i.e. the LED string is split in 4 LED segments. It is obvious that in this particular case the circuit will use 4 tap diodes and 4 constant current sources. This particular case with 4 segments was chosen for the detailed description of the circuit operation, considering it is the case most frequently found in practical applications. The example is non-limiting, as according to the invention the series connected LED string may be split in any number of segments, for example 1, 4, 9, etc. Generally, a circuit with a number of N segments will employ a number of N tap diodes and a number of N constant current sources.

The capacitor C_1, as shown in Figures 5, 8, 9, 10 and 11, will store the energy sunk from the power grid at a rate set by the direct AC driver, but will supply it to the LED string at a quasi-constant pace. Thus, the capacitor will perform the decoupling of the two processes: the grid sunk power process set by the direct AC driver and characterized by an approximately $\sin^2$ variation law, and respectively the LED series power supply process done at a quasi-constant rate.

The circuit shown in Figure 5 functions as following : when connecting the AC voltage from the public power grid to the AC leads of the rectifier bridge PR, the AC voltage is rectified and fed to the parallel group formed by the LED string and the capacitor C_1 respectively. Initially, the capacitor is discharged and the voltage drop at its leads is 0 Volts. This makes the instantaneous voltage potential on the anode of tap diode D_4 to equal the instantaneous value of the rectified voltage; depending on the connecting instance to the power grid, the magnitude of the instantaneous voltage can have any value between 0Vcc and the maximum of 325Vcc. Thus, to protect the current source connected to the tap diode D_4 cathode against the high values of the instantaneous voltage, as well as to offer a rapidly charging path to the capacitor C_1, it was introduced the varistor MOV. As soon as the value of the voltage drop at the leads of the capacitor C_1 exceeds some 230 V, the presence of the varistor MOV will no longer influence the operation, the charging of the capacitor C_1 being done exclusively through the direct AC driver. Thus, the capacitor C_1 is charged exclusively through the constant current source connected to the tap Diode D_4 cathode and is discharged exclusively through the series connected LED string.

We shall consider the sine power grid voltage passes through zero at the arbitrary chosen reference instant, $t_0=0$. The discharge current of the capacitor C_1 flows through the L_1, L_2, L_3 and L_4 series connected LED segments, until the instantaneous value of the grid voltage becomes greater than the voltage drop on the L_1 LED segment. At the moment the instantaneous value of the grid voltage exceeds the voltage drop on the L_1 LED segment, the direct AC driver switches on the constant current source connected to the tap diode D_1 cathode and the current through the L_1 LED segment increases by the current value set by the constant current source. The first result of this current increase through L1 segment is the increase of the voltage drop on the L_1 LED segment subsequent to the new value of the current flowing through it, leading to a decrease of the voltage available to L_2, L_3 and L_4 LED segments, which becomes equal to the difference between the voltage drop on the capacitor C_1 leads and the voltage drop on the L_1 LED segment, which in turn lead to a lower discharge current of the capacitor C_1.

When the instantaneous value of the grid voltage exceeds the summed voltage drop on the L_1 and L2 LED segments, the direct AC driver switches off the constant current source S_1 connected to the tap diode D_1 cathode and switches on the constant current source S_2 connected to the tap diode D_2 cathode. Subsequently, the current flowing through L_1 and L_2 LED segments increases by the value set by the constant current source S_2, which leads to a larger voltage drop on L_1 and L_2 LED segments, given to the new larger current. Subsequently, the voltage available for L_3 and L_4 LED segments decreases, which leads in turn to an even lower discharge current of the capacitor C_1.

When the instantaneous value of the grid voltage exceeds the summed voltage drop on L_1, L_2 and L_3 LED segments, the direct AC driver switches off the constant current source S_2 connected to the tap diode D_2 cathode and switches on the constant current source S_3 connected to the tap diode D_3 cathode. The current flowing through L_1, L_2 and L_3 LED segments increases with respect to the discharge current of the capacitor by the value set by the S_3 current source, which leads to a larger voltage drop on L_1, L_2 and L_3 LED segments given the new, larger current. Subsequently, the voltage available for L_4 LED segment decreases even more, further decreasing the discharge current of the capacitor C_1.

When the instantaneous value of the grid voltage exceeds the summed voltage drop on L_1, L_2, L_3 and L_4, LED segments, the direct AC driver switches off the constant current source S_3 connected to the tap diode D_3 cathode and switches on the constant current source S_4 connected to the tap diode D_4 cathode. The load of the constant current source S_4 becomes the parallel group formed by the series connected L_1, L_2, L_3, L_4 LED segments and the capacitor C_1, respectively. Thus, the current flowing through the LEDs will correspond to the voltage drop on the leads of the capacitor C_1. The capacitor C_1 will be charged with a constant current equal to the difference between the constant current set by the constant current source S_4 and the current flowing through the LEDs.

The capacitor continues to charge until the instantaneous value of the grid voltage decreases again under the voltage drop on its leads, when the direct AC driver switches off the constant current source S_4 connected to the tap diode D_4 cathode and switches on the constant current source S_3 connected to the tap diode D_3 cathode. In this moment the charge of the capacitor C_1, i.e. the storage of electric energy in it ceases and the discharge begins. The current flowing through L_1, L_2 and L_3 LED segments equals the discharge current of the capacitor C_1 to which is added the current set by the constant current source S_3; the current flowing through L_4 LED segment stay equal to the discharge current of the capacitor.

When the instantaneous value of the grid voltage decreases under the summed voltage drop at the leads of L_1, L_2 and L_3 LED segments , the direct AC driver switches off the constant current source S_3 connected to the tap diode D_3 cathode and switches on the constant current source S_2 connected to the tap diode D_2 cathode. The current flowing through L_1 and L_2 LED segments equals the discharge current of the capacitor C_1 plus the current set by the constant current source S_2, and respectively the current flowing through L_3 and L_4 LED segments equals the discharge current of the capacitor C_1.

When the instantaneous value of the grid voltage decreases under the summed voltage drop on the leads of L_1 and L_2 LED segments, the direct AC driver switches off the constant current source S_2 connected to the tap diode D_2 cathode and switches on the constant current source S_1 connected to the tap diode D_1 cathode. The current flowing through L_1 LED segment equals the discharge current of the capacitor C_1 plus the current set by the constant current source S_1, and respectively the current flowing through L_2, L_3 and L_4 LED segments equals the discharge current of the capacitor C_1.

When the instantaneous value of the grid voltage decreases under the voltage drop on the leads of L_1 LED segment, the direct AC driver switches off the constant current source S_1 connected to the tap diode D_1 cathode. The current flowing through L_1, L_2, L_3 and L_4 LED segments equals the discharge current of the capacitor C_1.

Through L_1, L_2, L_3 and L_4 LED segments flows a current equal to the discharge current of the capacitor C_1 during the whole time the instantaneous value of the grid voltage is smaller than (inclusive zero) the voltage drop on the L_1 LED segment. This fact has two consequences: first, the LEDs will light continuously, including around the zero passing of the grid voltage, making the light engine light continuously, and second it is smoothing the light profile, thus dramatically enhancing the flicker index.

Figure 8 shows a circuit according to the invention, which comprises:

- A rectifier bridge PR whose positive output is series-connected to the anode of a string made of a plurality of series-connected LED segments L_1, L_2,..., L_N;
- A control circuit which controls a plurality of constant current sources S_1, S_2,..., S_N;
- Each constant current source S_1, S_2,..., S_N having the cathode connected to the tap between the SENS lead of the control circuit and the lead connected to the SENS lead of a resistor R_{SET}, the resistor R_{SET} having its other lead connected to the ground;
- A capacitor C_1 set in parallel with the string made of the LED segments L_1, L_2,..., L_N, a lead of the capacitor C_1 being connected to the anode of the first LED of the first segment L_1, and the other lead of the capacitor C_1 being connected to the cathode of the last LED of the last segment L_N;
- Tap diodes D_1, D_2,..., D_N

  # whose anodes are connected respectively to the tap between the segments L_1 and L_2, respectively to the tap between the segments L_2 and L_3, and so on, respectively to the tap between the segments L_{N-1} and L_N, respectively to the cathode of the last LED of the last segment L_N;

  # and whose cathodes are connected respectively to the anode of each one of the constant current sources S_1, S_2,..., S_N;

- A varistor MOV having a lead connected to the cathode of the tap diode D_N and the other lead connected to the ground.

Figure 9 shows a circuit according to the invention which, compared to the circuit from figure 8, further comprises a capacitor C_2 set between the anodes of the tap diodes D_{N-1} and D_N, as well as a resistor R_1 set between the positive output of the rectifier bridge PR and the anode of the first LED of the segment L_1.

The resistor R_1 limits the in rush current of the capacitor C_1, which increases the operation life of the capacitor C_1.

The current flowing through the last segment of LEDs L_N, and having the profile shown in figure 7, may generate harmonics in excess of the harmonic standard EN61000-3-2 limits.

The capacitor C_2 filters these harmonics below the limits set by the harmonic standard EN61000-3-2.

As an example, for any value of the number of segments N, R1 may have a value of some 200 ohm, C_1 may have a value of 10-20 µF (in which case the in rush current of C_1 may reach 1,5 A) and C_2 may have some 100 nF. The varistor MOV may be, for example, a 5mm diameter disc varistor.

The current ratios i_1 / i_2/... / i_N of the most popular direct drive integrated circuits are fixed, their effective values being set with only one resistor R_{SET}. The voltage drop on R_{SET} given the instantaneous current flowing through it and through a number of series connected LED segments is compared to a reference voltage Vref at the SENS lead. Based on this comparison, the control circuit enables or disables incrementally/decrementally a current source S_1, S_2,..., S_N switching on or off, successively, the LED segments, and providing the desired profile of the current sunk by the direct AC driver from the grid.

We will use hereinafter the term “dimming” for the variation of the power sunk from the power grid or of the luminous flux radiated by the LEDs.

Dimming of the light source can be achieved by varying R_{SET}. But the variation of R_{SET} is not a wise strategy, given that through R_{SET} are flowing large currents, namely the currents through LEDs. In practical applications R_{SET} ranges around tens of ohms and therefore Vref ranges in hundreds of mV.

Noticing the reference voltage Vref is set to the lowest voltage potential in the schematic, which is GND, and also noticing that through the GND lead do not flow large currents (the currents through LEDs), but only the currents biasing the control circuit, it was identified a new light engine dimming method by varying the voltage potential of the GND reference lead.

The maximum current flowing through the LEDs is: $i_N = (Vref-V_{GND}) : R_{SET}$, where Vref is relative to the potential of the GND voltage potential.

By varying V_{GND} the voltage potential of the GND lead it is possible to modify the currents i_1, i_2,..., i_N, set by the sources S_1, S_2,..., S_N, and flowing through the LEDs, and implicitly dim the power sunk by the light engine from the grid.

The dimming control voltage U_{DIM} is supplied to the schematic through the resistive voltage divider R_A/R_B translating the standard variation of U_{DIM} between 0 and -10V relative to the ground, to a reference potential variation of the GND lead between 0 and -Vref.

When the voltage potential of the GND reference lead is 0 V, the direct AC driver sinks the nominal current for which it was set. By decreasing the voltage potential of the reference GND lead, the power sunk by the direct AC driver is decreasing, to the point in which when the voltage potential of the GND reference lead becomes equal (and of contrary sign) to the internal reference voltage Vref, the direct AC driver sinks no current and thus the LEDs are no more lighting.

For applying the above mentioned dimming technique, to the method of reduction the flicker index of a constant current direct AC driver described in the last paragraph of page 3 and first paragraph of page 4, it is further added the step of variation between 0 and -10V of the voltage potential of the GND lead of the control circuit that controls the constant current sources S_1, S_2,..., S_N of the direct AC LED driver.

Figure 10 shows a circuit according to the invention, in which the light source is dimmed. Mainly, it is the same circuit as shown in figure 9 to which a resistor R_B is further added, having one lead connected to the ground and the second lead connected to the GND lead of the control circuit as well as a resistor R_A having one lead to which a dimming voltage U_{DIM} is applied and the second lead connected to the GND lead of the control circuit.

The light engines shown in figures 5 and 8 can be dimmed as described in the previous paragraph, by adding the resistors R_A and R_B to the schematic and by applying the voltage U_{DIM}.

When the schematic shown in figure 10 is not dimmed, i.e. when $U_{DIM}=0$, it exhibits a positive thermal reaction: its heating increasing the bias current of the control circuit, which, in turn, increases the current set by the constant current sources S_1, S_2,..., S_N, which in turn increase the temperature of the schematic. The thermal stabilization of the said circuit is done by setting a diode D_B in parallel to the resistor R_B. The voltage drop on the PN junction of diode D_B decreases with the temperature, so that with an increase in the circuit temperature, the voltage potential of the GND lead decreases, thus being closer to the ground potential, which makes the currents set by the constant current sources, S_2,..., S_N, to decrease, and as a result to lower the temperature of the circuit.

Figure 11 shows a thermally stabilized schematic according to the invention. It is mainly the schematic shown in figure 10 that was thermally stabilized by adding a diode D_B having its anode connected to the GND lead of the control circuit and the cathode connected to the ground.

The thermal stabilization can be done as described in the previous paragraph (by adding a properly connected diode D_B) to the schematic shown in figure 10 where the resistor R_1 and the capacitor C_2 are missing.

In order to reduce the overall size of any of the circuits according to the invention, the capacitor C_1 may preferably be an electrolytic capacitor.

CLAIMS

1. Method of reducing the flicker index of a constant current direct AC LED driver, **characterized in that** it comprises the step of:

- flowing a current through the segments (L_1, L_2,..., L_N) of a LED string, when the power grid voltage value is smaller than the voltage drop on the string made of the segments (L_1, L_2,..., L_N), the flowing current equaling the discharge current of a capacitor (C_1) set in parallel with the string made of the segments (L_1, L_2,..., L_N), one lead of the capacitor (C_1) being connected to the anode of the first LED of the first segment (L_1), and the other lead of the capacitor (C_1) being connected to the cathode of the last LED of the last segment (L_N).

2. Method according to claim 1, **characterized in that** it further comprises the step of:

- variation between 0 and -10V of the voltage potential of the lead (GND) of the control circuit that controls the constant current sources (S_1, S_2,..., S_N) of the direct AC LED driver.

3. Circuit associated to the method of claim 1, which comprises:

- a rectifier bridge (PR) whose positive output is series-connected to the anode of a string made of a plurality of series-connected LED segments (L_1, L_2,..., L_N);
- a control circuit which controls a plurality of constant current sources (S_1, S_2,..., S_N);
- each constant current source (S_1, S_2,..., S_N) having the cathode connected to the tap between the lead (SENS) of the control circuit and the lead connected to the lead (SENS) of a resistor (R_{SET}), the resistor (R_{SET}) having its other lead connected to the ground;

characterized in that the circuit further comprises:

- a capacitor (C_1) set in parallel with the string made of the LED segments (L_1, L_2,..., L_N), a lead of the capacitor (C_1) being connected to the anode of the first LED of the first segment (L_1), and the other lead of the capacitor (C_1) being connected to the cathode of the last LED of the last segment (L_N);
- tap diodes (D_1, D_2,..., D_N)

whose anodes are connected respectively to the tap between the segments (L_1) and (L_2), respectively to the tap between the segments (L_2) and (L_3), and so on, respectively to the tap between the segments (L_{N-1}) and (L_N), respectively to the cathode of the last LED of the last segment (L_N);

and whose cathodes are connected respectively to the anode of each one of the constant current sources (S_1, S_2,..., S_N);

- a varistor (MOV) having a lead connected to the cathode of the tap diode (D_N) and the other lead connected to the ground.

4. Circuit according to claim 3, **characterized in that** the circuit further comprises:

- a capacitor (C_2) set between the anodes of the tap diodes (D_{N-1}) and (D_N);
- a resistor (R_1) set between the positive output of the rectifier bridge (PR) and the anode of the first LED of the segment (L_1).

5. Circuit according to any of the claims 3 or 4, associated to the method from claim 2, **characterized in that** the circuit further comprises:

- a resistor (R_B) having a lead connected to the ground and the second lead connected to the lead (GND) of the control circuit;
- a resistor (R_A) having a lead to which a dimming voltage (U_{DIM}) is applied, and the second lead connected to the lead (GND) of the control circuit.

6. Circuit according to claim 5, **characterized in that** the circuit further comprises:

- a diode (D_B) having its anode connected to the lead (GND) of the control circuit and its cathode connected to the ground.

7. Circuit according to any of the claims 3-6, **characterized in that** the capacitor (C_1) is an electrolytic capacitor.

DRAWINGS

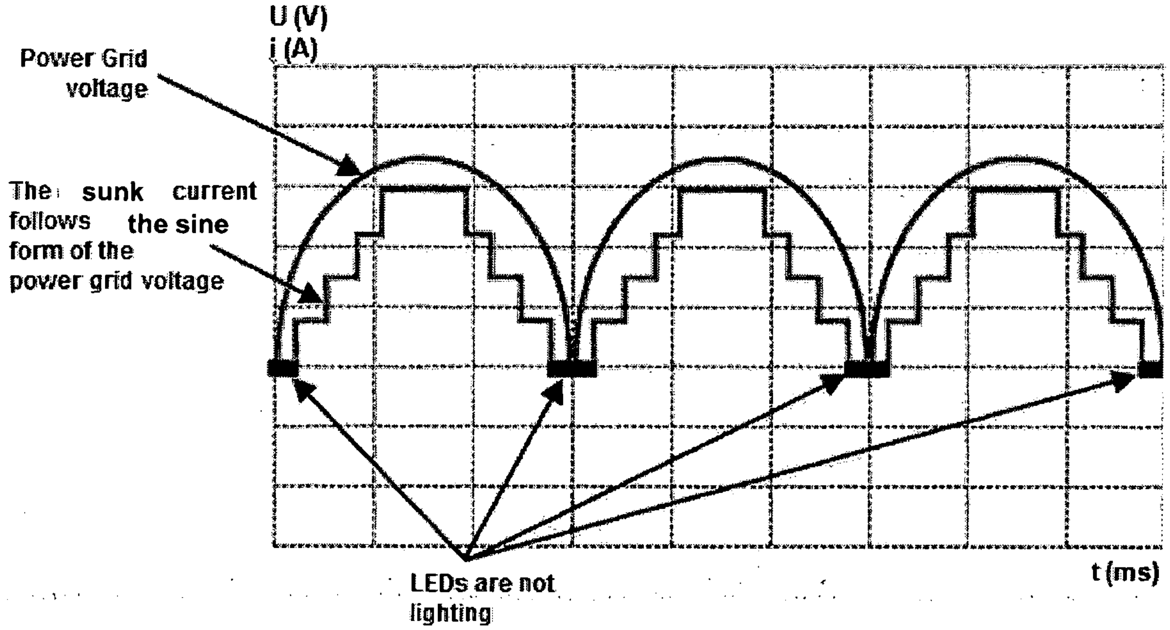

Fig. 1 The time intervals during which the direct AC solutions are not lighting

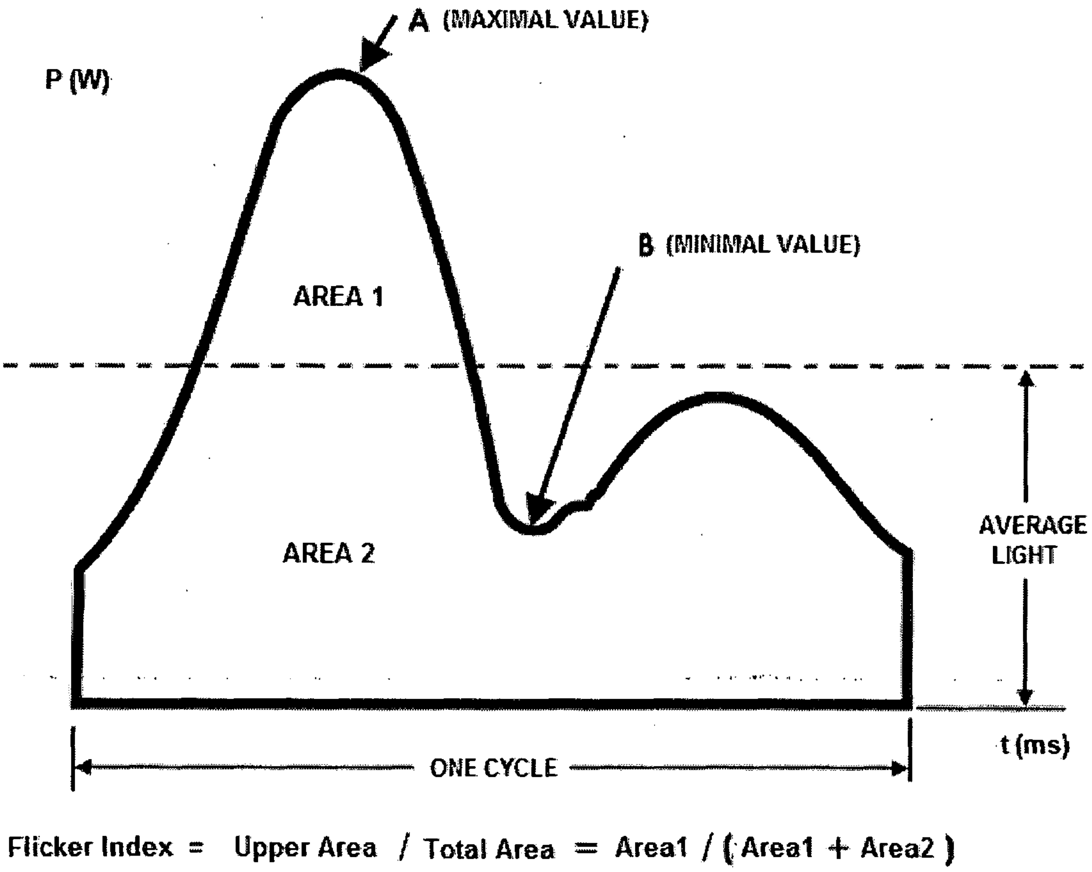

Fig. 2 The reference profile for defining the flicker index

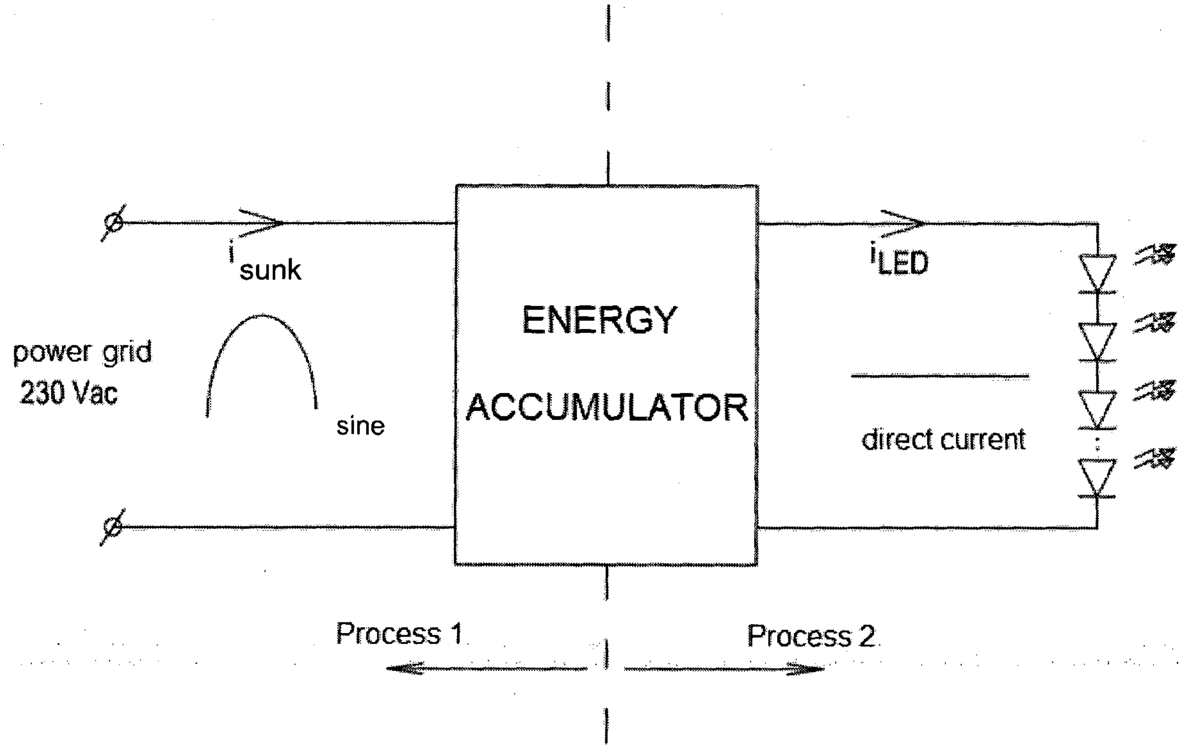

Fig. 3 The decoupling principle

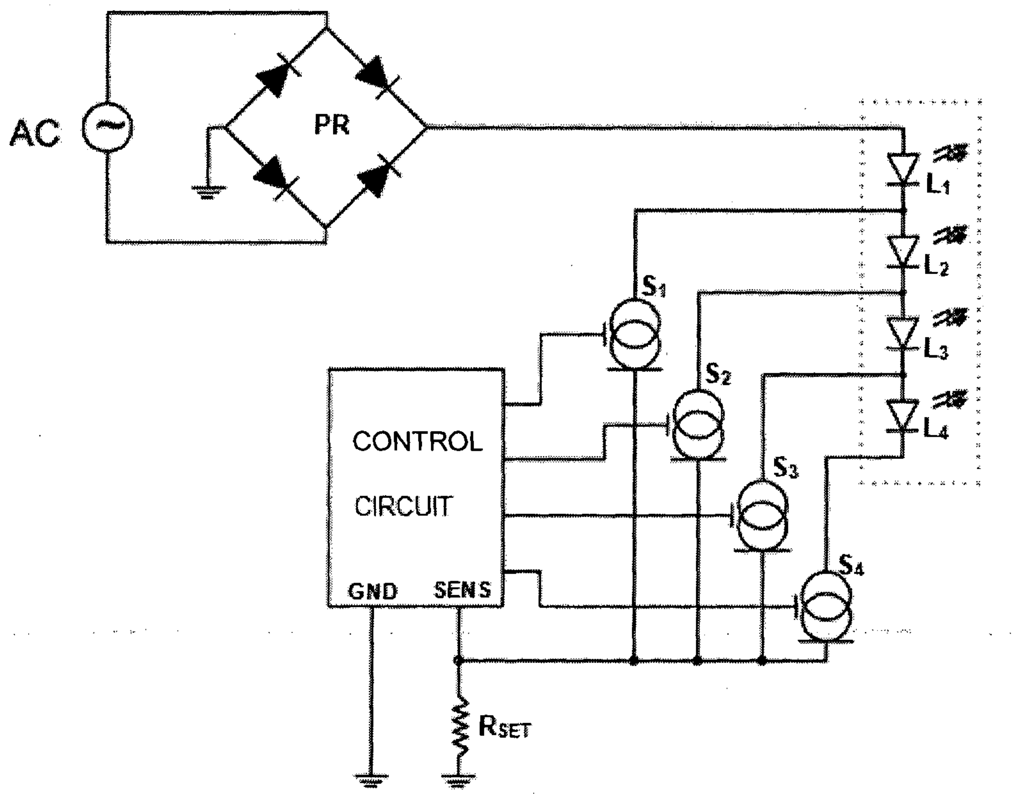

Fig. 4 The electric diagram of a direct AC driver with 4 segments – the state of the art

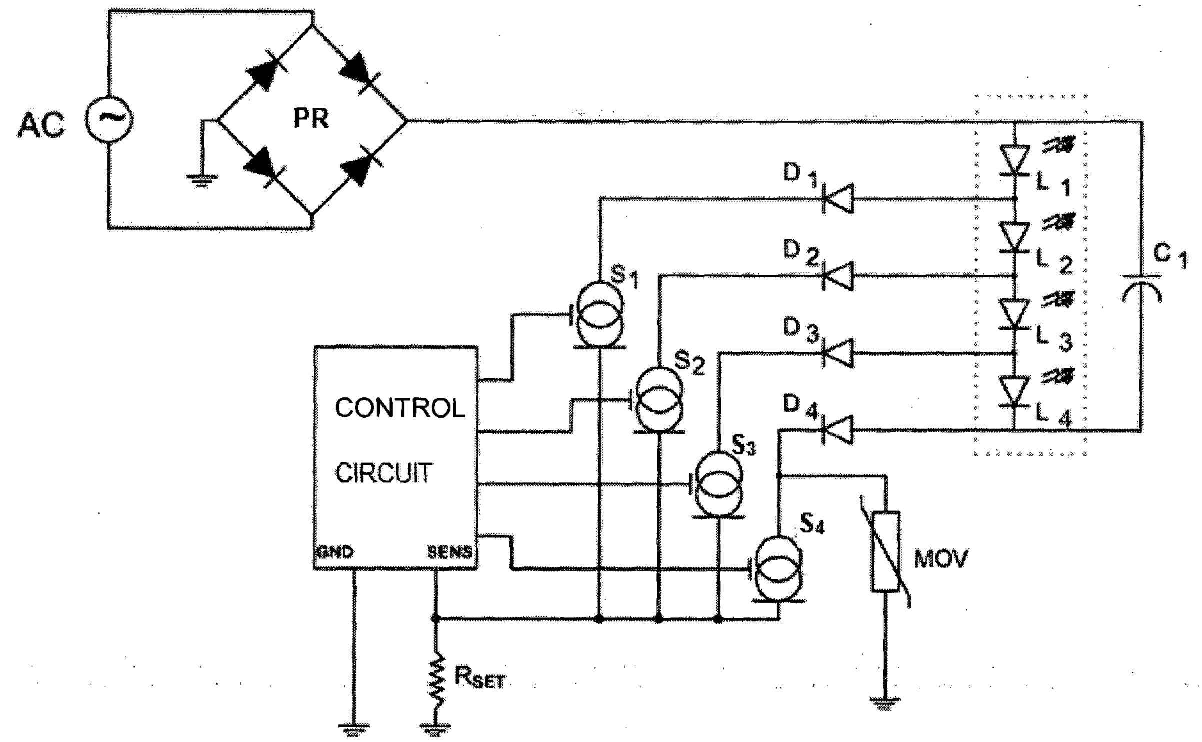

Fig. 5 The electric diagram of the circuit according to the invention for reducing the flicker index, for 4 segments

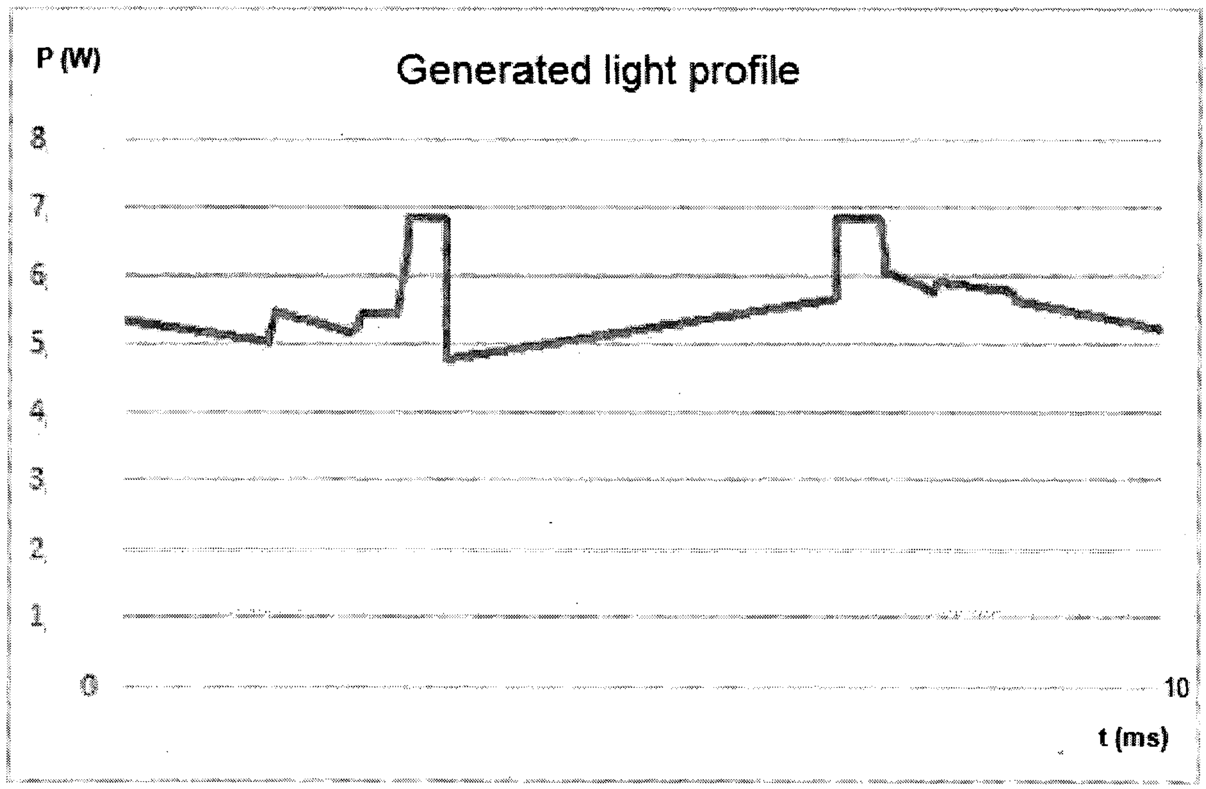

Fig. 6 The profile of the light emitted by the circuit in Fig. 5

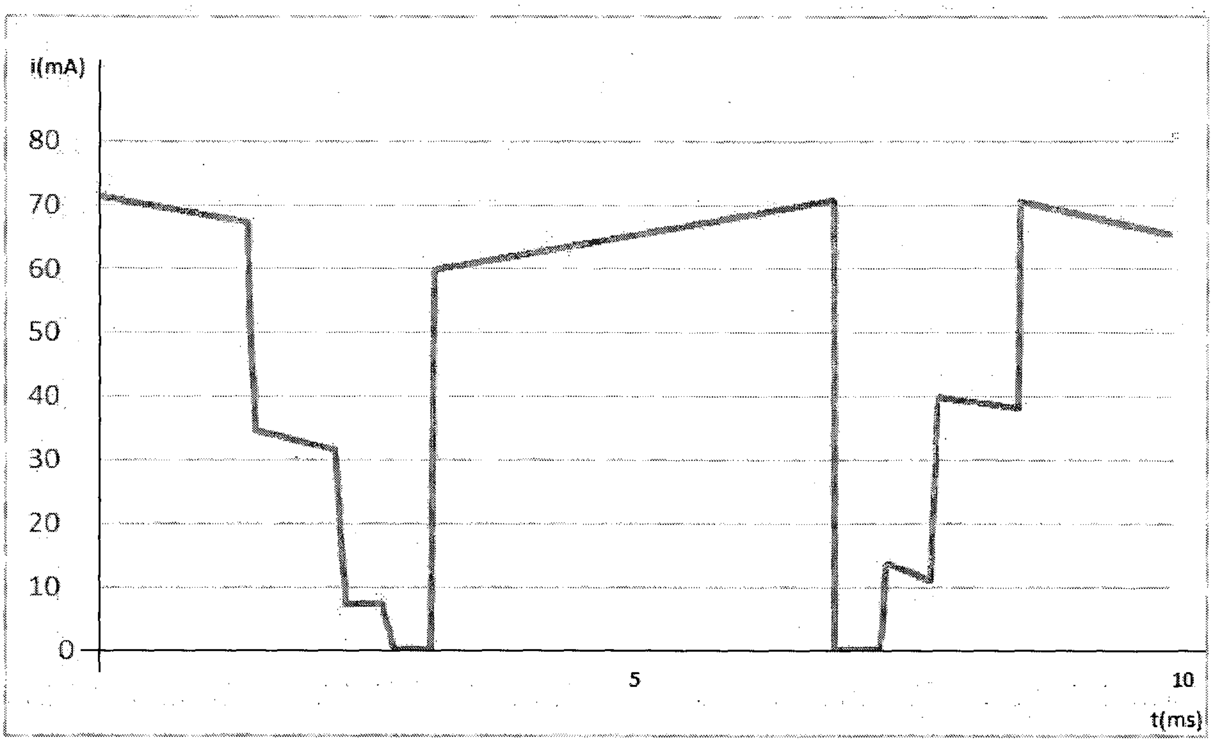

Fig. 7 The profile of the current flowing through the last segment of LEDs L_N

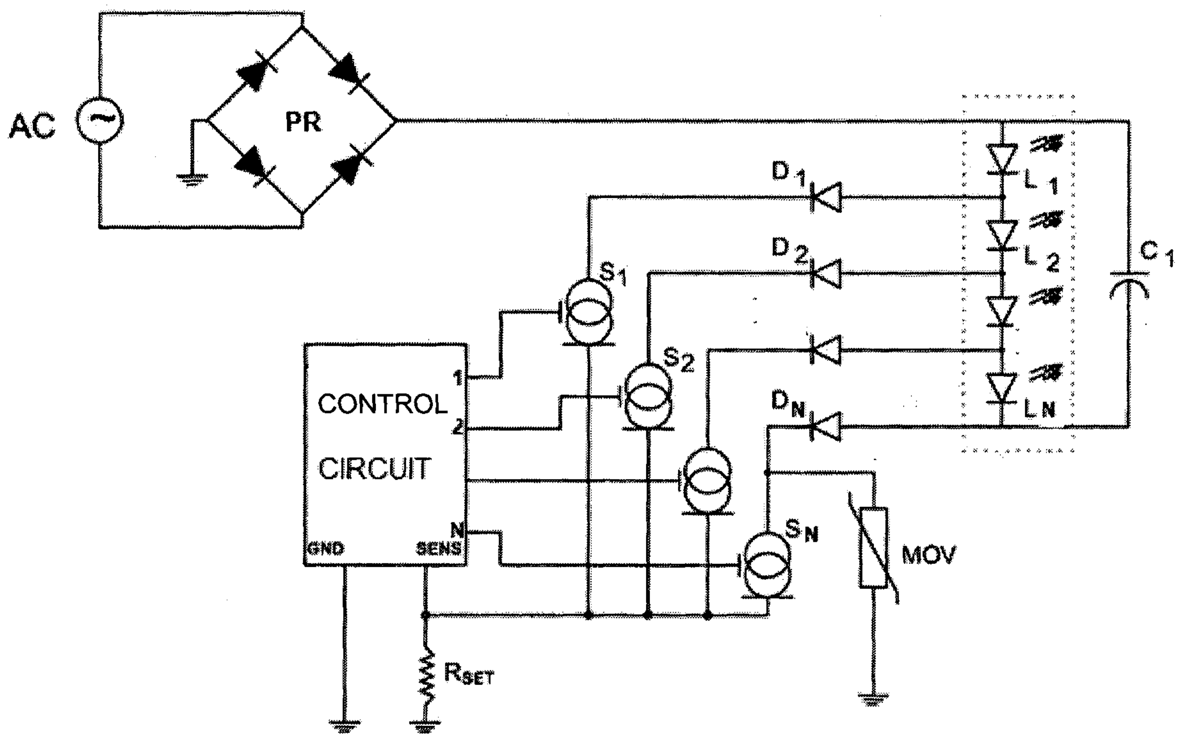

Fig. 8 The generalized electric diagram of the circuit according to the invention for reducing the flicker index, for N segments

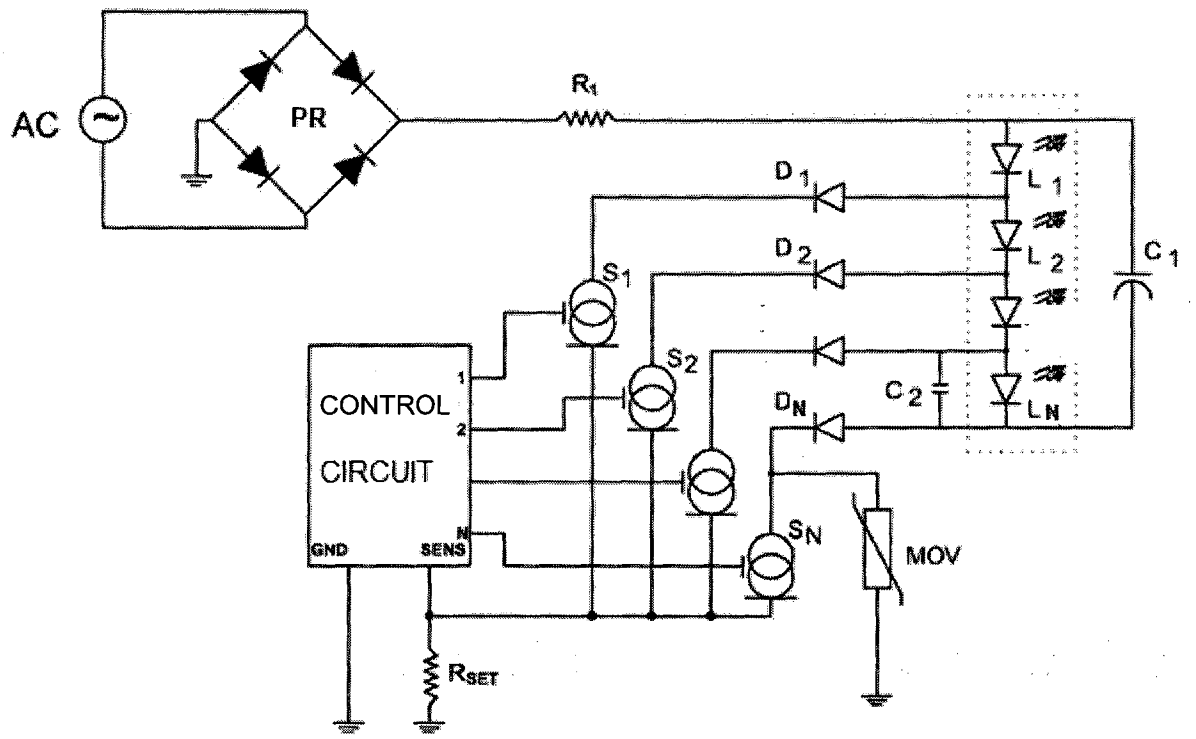

Fig. 9 The generalized electric diagram of the circuit according to the invention for reducing the flicker index, for N segments - variant

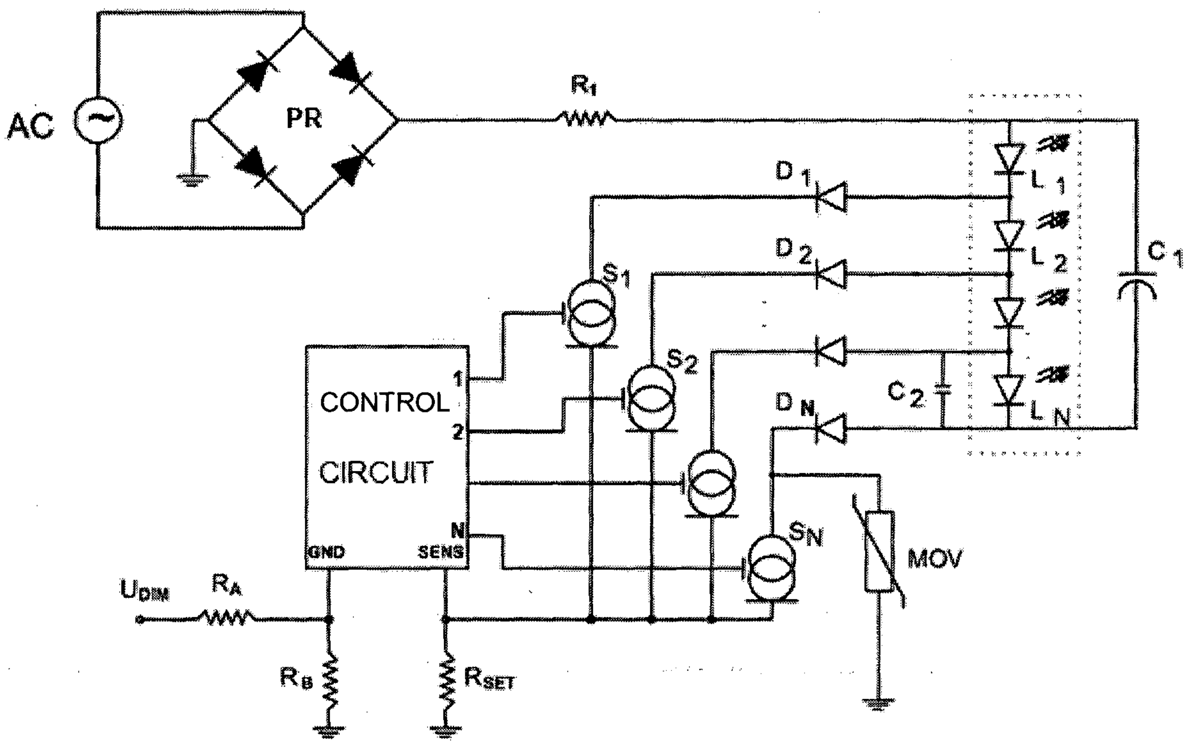

Fig. 10 The generalized electric diagram of the circuit according to the invention for reducing the flicker index, for N segments - variant with dimmable source

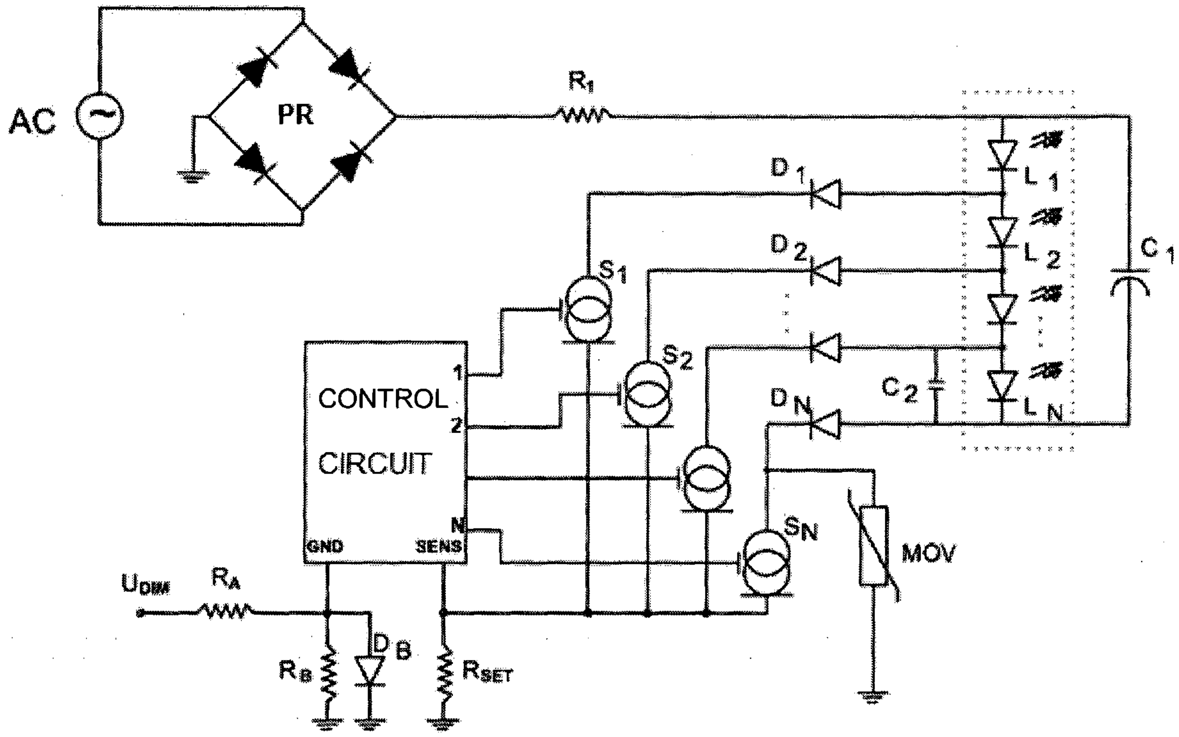

Fig. 11 The generalized electric diagram of the circuit according to the invention for reducing the flicker index, for N segments – variant with thermal stabilization