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(54) **Method for driving a LED**

(57) The present invention relates to a method for driving a LED and to an illumination system comprising at least one LED.

According to the present invention that LED is supplied with a driving pulse signal at a cycle equal to a unit of time, wherein said driving pulse signal having a peak value equal to n times of a prescribed current value and a duration of T/n', and n/n' ≦ 1.

Thereby the light intensity is increased by n times while the power consumption is the same in comparison to driving that LED with a prescribed constant driving voltage and the prescribed constant driving current.

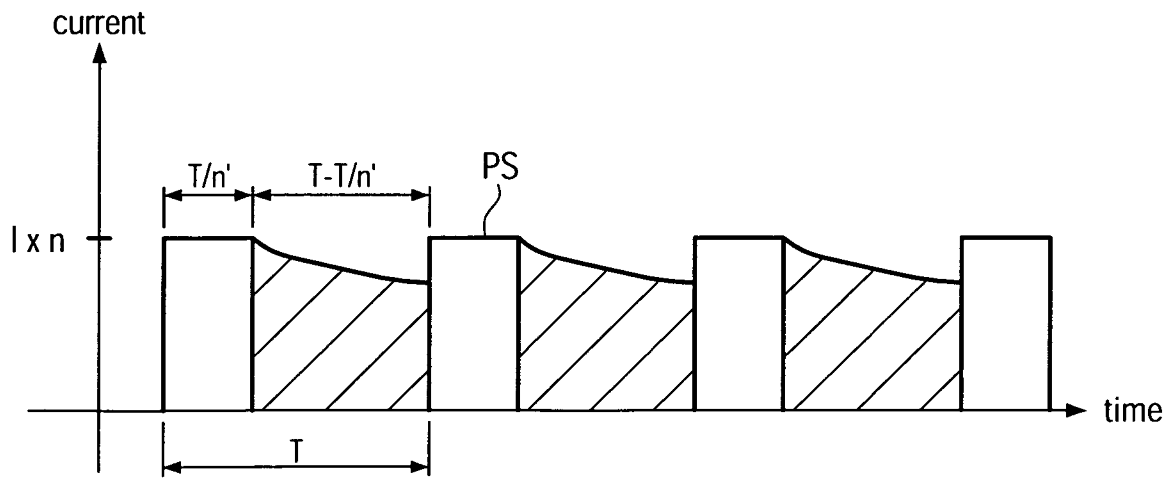

FIG. 8

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Description

BACKGROUND OF THE INVENTION

[0001] The present invention relates to a method for driving a LED, and more particularly, to a method for driving a LED which can effectively enhance the light intensity of a LED.

[0002] Recently, the tendency of using Light-Emitting Diodes as light source for electronic devices, lighting devices, etc. is continuously increasing. However, in order to completely replace with LEDs the traditional light sources, especially the indoor lighting devices, the intensity of the light emitted by the LEDs must be greatly enhanced.

SUMMARY OF THE INVENTION

[0003] The present invention provides a method for driving a LED which can enhance the light intensity of a LED.

[0004] One aspect of the present invention is a method for driving a LED which if it is operated at a prescribed constant driving voltage and a prescribed constant driving current then the prescribed power consumption of said LED in a prescribed unit of time were the prescribed constant driving voltage times the prescribed constant driving current, comprising the step of supplying said LED with a driving pulse signal at a cycle equal to the prescribed unit of time, said driving pulse signal having a peak value equal to n times of current value of the prescribed constant driving current and a high voltage level duration of T/n', wherein T is the prescribed unit of time, and n/n' ≦ 1, thereby the intensity of the light emitted from the LED is increased by n times while the power consumption is kept unchanged. According to an advantageous embodiment n and n' both are positive integer excluding 0 and 1.

[0005] Other aspects and advantages of the present invention will become apparent from the following description, taken in conjunction with the accompanying drawings, illustrating by way of example the principles of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0006] The invention, together with objects and advantages thereof, may best be understood by reference to the following description of the presently preferred embodiments together with the accompanying drawings in which:

Fig. 1 shows a waveform of a conventional driving current signal for a light-emitting diode (LED);

Fig. 2 is a diagram showing the relationship between the brightness of a LED and the magnitude of driving current;

Figs. 3 shows a waveform of a driving pulse signal used in a method of driving a LED according to the present invention;

Fig. 4 shows an exemplary example of a waveform of a driving pulse signal used in the method of driving a LED according to the present invention;

Fig. 5 shows another exemplary example of a waveform of a driving pulse signal used in the method of driving a LED according to the present invention;

Fig. 6 shows another exemplary example of a waveform of a driving pulse signal used in the method of driving a LED according to the present invention;

Fig. 7 is a schematic diagram of a LED which is coated with an photoluminescent material and which is driven by the method according to the present invention;

Fig. 8 is a schematic diagram for explaining the effect of the photoluminescent material coated on the LED shown in Fig. 7;

Fig. 9 is a schematic diagram for explaining the principle of the method according to the present invention;

Figs. 10 to 12 show exemplary examples of waveform of driving pulse signals used in the method according to the present invention;

Figs. 13 to 15 are schematic circuit diagrams of the driving circuitries adapted to be used in the method according to the present invention;

Fig. 16 is a schematic diagram showing various LED array examples adapted to be driven by the method according to the present invention; and

Figs. 17 to 18 are schematic diagrams for explaining how flickering phenomenon is prevented from occurring by using the photoluminescent material coated on a LED when the LED is driven by the method according to the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0007] In the drawings, like numerals are used for like elements throughout.

[0008] An embodiment of the present invention will now be discussed with reference to the drawings.

[0009] Fig. 1 shows a waveform of a conventional driving current signal DS for a light-emitting diode (LED) which is operated at a prescribed constant driving voltage of V and a prescribed constant driving current of I such that the prescribed power consumption P of the LED in a prescribed unit of time T is V x I. For a LED which is operated at a prescribed constant driving current of 350 mA and a prescribed constant driving voltage of 1 V to emit light with an intensity of 30 lx, as the current value of the driving current signal DS is increased, the light intensity increases accordingly, based on the relationship between the current value of the driving current signal and the light intensity shown in Fig. 2. For example, if the current value of the driving current signal DS is doubled to 700 mA (=350 mA x 2), the light intensity will approximately increase to 60 lx. However, the power consumption P of the LED in a unit of time T will also be doubled, that is 2 W(=3.5V x 700mA). It should be appreciated that the LED having the characteristics shown in Fig. 2 is available in the market.

[0010] Referring to Fig. 3, a driving pulse signal PS used in the method of the present invention is shown. It can be seen from Fig. 2, the light intensity will increase as the current value of the driving current signal is increased. Therefore, in the method of the present invention, a driving pulse signal PS, the cycle of which is equal to the prescribed unit of time T, is provided to the LED. The peak value of each of the pulse signals PS is n times the current value of the signal DS, and the high voltage level duration of the pulse signal PS is (T/n'), wherein n and n' are both positive integer excluding 0 and 1, and (n/n') ≦ 1. Therefore, during the high voltage level duration (T/n'), the power consumption of the LED is increased by n times because the current value of the driving pulse signal PS at its high voltage level is n times the current value of the signal DS, thereby increasing the light intensity n times. However, the total power consumption of the LED in the unit of time T is still equal to P (=V x (I x n) x 1/n'), therefore, the total power consumption is kept unchanged.

[0011] Referring to Fig. 4, if n is equal to 4, the current value of the current is 350 mA, the light intensity in the high voltage level duration T/n' increases 4 times. However, the total power consumption is still 1 W. Therefore, the total power consumption is unchanged while the light intensity increases n times.

[0012] It should be noted that, although the light intensity will increase as the current value of the driving current signal is increased, however, the number of times is not unlimited. As shown in Fig. 9, when the magnitude of the current is increased to some extent, the LED enters to the breakdown state. At this time, the light intensity will not increase anymore, even though the magnitude of the current is continuously increasing. The selection of n is in relation to the high voltage level duration (T/n'), and the selection of the high voltage level duration (T/n') is based on the effective slope of the current of the LED. In Fig. 9, as indicated by the thick broken lines, it is known that the LED is driven by a constant current value of 350 mA, only a portion (A) of the effective slope of the current is used. However, the whole effective slope (A+B) will be used in the present invention. Therefore, the intensity of the light emitted from the LED driven by the method of the present invention is substantially increased.

[0013] It should be noted that, the magnitude of the current in Fig. 9 is by way of example, the present invention is not limited thereto. On the other hand, the arrow indicates the loop formed by the rising edge, the high voltage level duration, and the falling edge of the pulse, that is, the conditions based thereupon the peak value of the pulse and the high voltage level duration is selected.

[0014] As described above, referring to Fig. 10, the LEDs are correspondingly driven by two identical driving pulse signals PS1,PS2 when the method of the present invention is used to drive two or more LEDs in series connection. Therefore, in comparison with Fig. 1, the light intensity will increase n x m times in the high voltage level duration (T/n'), wherein m is the number of LED and is 2 in the embodiment shown in Fig. 10.

[0015] Referring now to Figs. 5 and 12, the LEDs are correspondingly driven by two identical driving pulse signals PS1,PS2 when the method of the present invention is used to drive two or more LEDs in parallel connection. If the phases of the driving pulse signals PS1,PS2 are the same, that is, the driving pulse signals PS1,PS2 are synchronously provided to the corresponding LEDs, in comparision with Fig. 1, the light intensity will also increase n x m times in the high voltage level duration (T/n').

[0016] Referring now to Figs. 6 and 11, the LEDs are correspondingly driven by two driving pulse signals PS1,PS2' having different phases. The phases of the driving pulse signals PS1,PS2 are different, but the peak value and the cycle time are the same. The phase difference diff between the driving pulse signals PS1 and PS2'can be selected depending on what is needed.

[0017] For n = 4 and n' = 8, the power consumption of PS1 during the high voltage level duration (T/n') is 1400mA x 3.5V ≒ 4W, the power consumption of PS2' during the high voltage level duration (T/n') is 1400mA x 3.5V ≒ 4W. Therefore, the power consumption of PS1 in a unit of time T is about 0.5W, and the power consumption of PS2' is about 0.5W. Therefore, two parallel-connected 1400mA currents can increase 8W slope and the light intensity, but the power consumption in a unit of time T is still about 1W.

[0018] Referring to Figs. 7, 8, 17 and 18, in order to prevent flickering phenomenon from occurring at the time of (T-(T/4)), the cap surface of the LED will be coated with a photoluminescent material which can absorb the ambient light and emit the absorbed light, such that the photoluminescent material will emit the light absorbed during the high voltage level duration (T/4) during the low voltage level duration (T-(T/4)). As shown in Fig. 8, the shadow portion is the low voltage level duration (T-(T/4)) during which the photoluminescent material release the stored photo energy. It should be noted that, the intensity of light emitted from the photoluminescent material is about 80% of that from the LED. As shown in Fig. 17, the low energy level L is a level corresponding to the low voltage level of the driving pulse signal, the high energy level H is a level corresponding to the high voltage level of the driving pulse signal, and the excitation energy level E is a level above which the LED emits light. A cycle from the low energy level to the high energy level, from the high energy level to the excitation energy level, and from the excitation energy level total takes 100 nsec. It should be noted that, when the driving pulse signal transits from the low voltage level to the high voltage level, the LED emits light, and the photoluminescent material on the LED absorbs and stores the photo energy from the emitted light. When the driving pulse signal transits from the high voltage level to the low voltage level, the LED will cease to emit light after down from the excitation energy level E to the low energy level L. In the meantime, the photoluminescent material will release the stored photo energy until the driving pulse signal transits from the low voltage level to the high voltage level. Therefore, in order to prevent flickering phenomenon from occurring at the time of (T-(T/4)), a condition that the duration during which the photoluminescent material coated on a LED releases stored photo energy is greater than the pulse cycle, and the pulse cycle is greater than 100 nsec., must be satisfy.

[0019] It should be noted that, the photoluminescent material may be doped with fluorescent powder or phosphorus powder. On the other hand, the LED shown in Fig. 7 is by way of example, the photoluminescent material may be coated on the lighting surface of any LED package.

[0020] Figs. 13 to 15 are three LED driving circuitry examples that are adapted to be used in the present invention. Fig. 16 is a schematic diagram showing various LED array examples adapted to be driven by the method according to the present invention.

[0021] Additionally, in order to further prevent flickering phenomenon from occurring, the frequency of the driving pulse signal may be set to 32Hz or above.

[0022] The present examples and embodiments are to be considered as illustrative and not restrictive, and the invention is not to be limited to the details given herein, but may be modified within the scope and equivalence of the appended claims.

[0023] Furthermore, it should be apparent to those skilled in the art that a conventional RC circuitry can also be used to prevent flickering phenomenon from occurring, instead of the photoluminescent material.

Claims

1. A method for driving a LED which if it is operated at a prescribed constant driving voltage and a prescribed constant driving current then the prescribed power consumption of said LED in a prescribed unit of time were the prescribed constant driving voltage times the prescribed constant driving current, comprising the steps of:

    supplying said LED with a driving pulse signal at a cycle equal to a unit of time, said driving pulse signal having a peak value equal to n times of the constant current value and a duration of T/n' and n/n' $\leqq$ 1.

2. A method according to claim 1, wherein n and n' both are positive integers excluding 0 and 1.

3. A method according to claim 1 or 2, further comprising the step of:

    coating a lighting surface of said LED with an photoluminescent material which can absorb the ambient light and emit the absorbed light, such that the photoluminescent material will emit the light absorbed during the pulse duration time (T/4) during the pulse intermittent time (T-(T/4)).

4. A method according to claim 3, wherein said photoluminescent material is doped with phosphor powder.

5. A method according to claim 3 or 4, wherein said photoluminescent material is doped with fluorescent powder.

6. A method according to any of the claims 1 to 5, in the step of supplying driving pulse signal, said LEDs are serially connected, such that the light intensity of said LEDs will be increased by nxm times during the pulse duration time T/n', wherein m is the number of said LEDs and is a positive integer excluding 0.

7. A method according to any of the claims 1 to 5, in the step of supplying driving pulse signal, said LEDs are connected in parallel, said driving pulse signal received by each of said LEDs has a different phase.

8. A method according to any of the claims 1 to 5, in the step of supplying driving pulse signal, said LEDs are connected in parallel, said driving pulse signal received by each of said LEDs has a same phase, such that during the pulse duration time, the light intensity of said LEDs will be increased by nxm times, wherein m is the number of said LEDs and is a positive integer excluding 0.

9. A method according to any of the claims 1 to 8, in the step of supplying driving pulse signal, said driving pulse signal has a frequency of at least 32Hz.

10. An illumination system comprising at least one LED, and
    a driving circuit being electrically connected to said at least one LED and being embodied to carry out the method according to one of the claims 1 to 9.

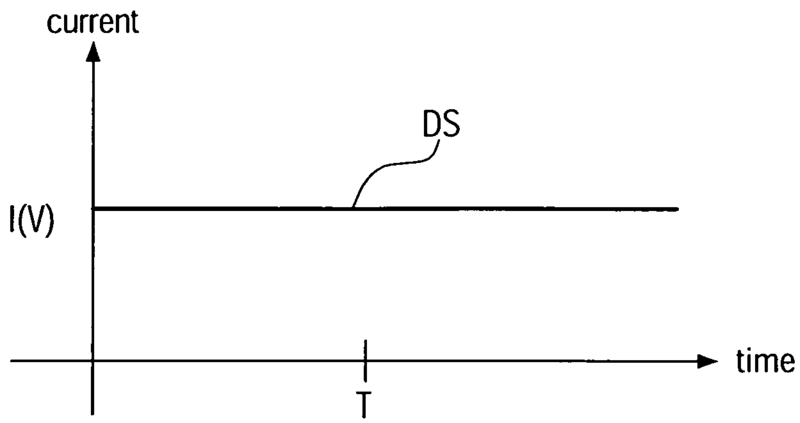
current
DS
I(V)
time
T

FIG. 1

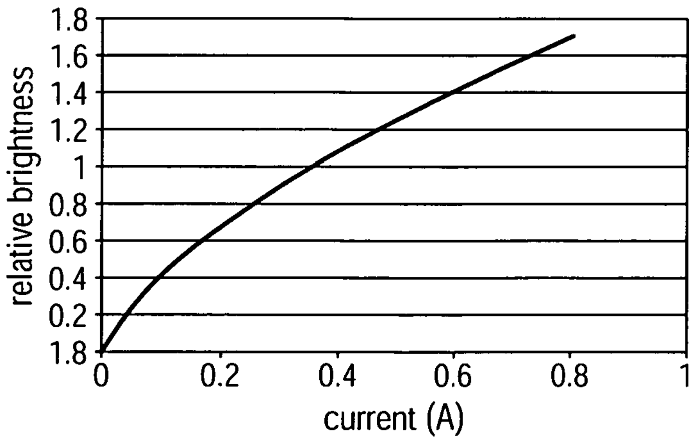
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
1.8
relative brightness
0
0.2
0.4
0.6
0.8
1
current (A)

FIG. 2

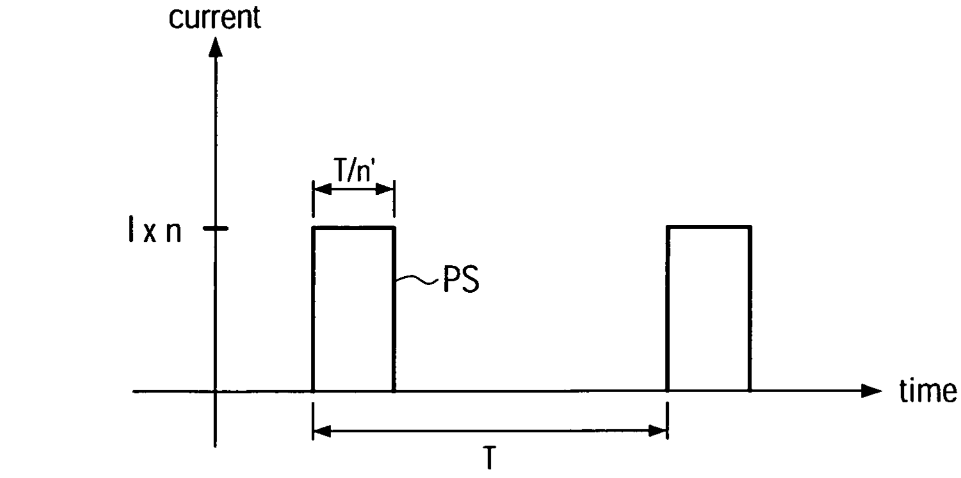

FIG. 3

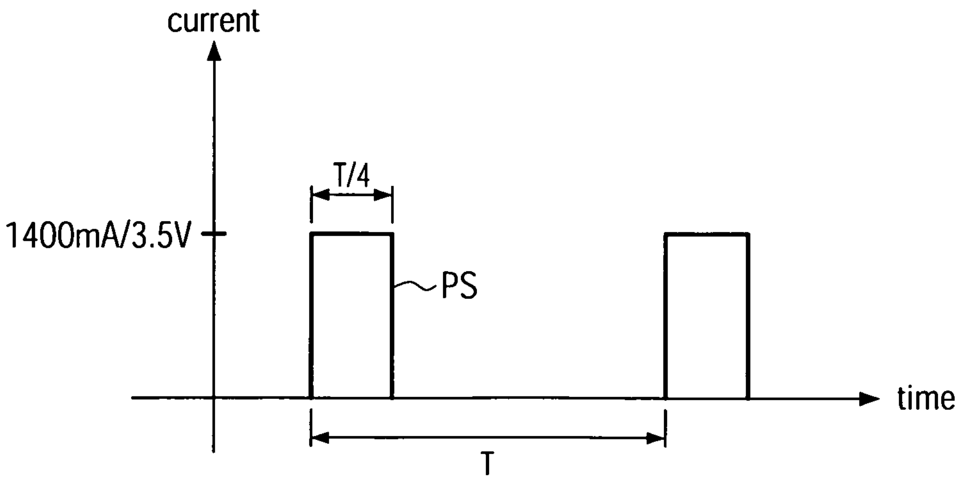

FIG. 4

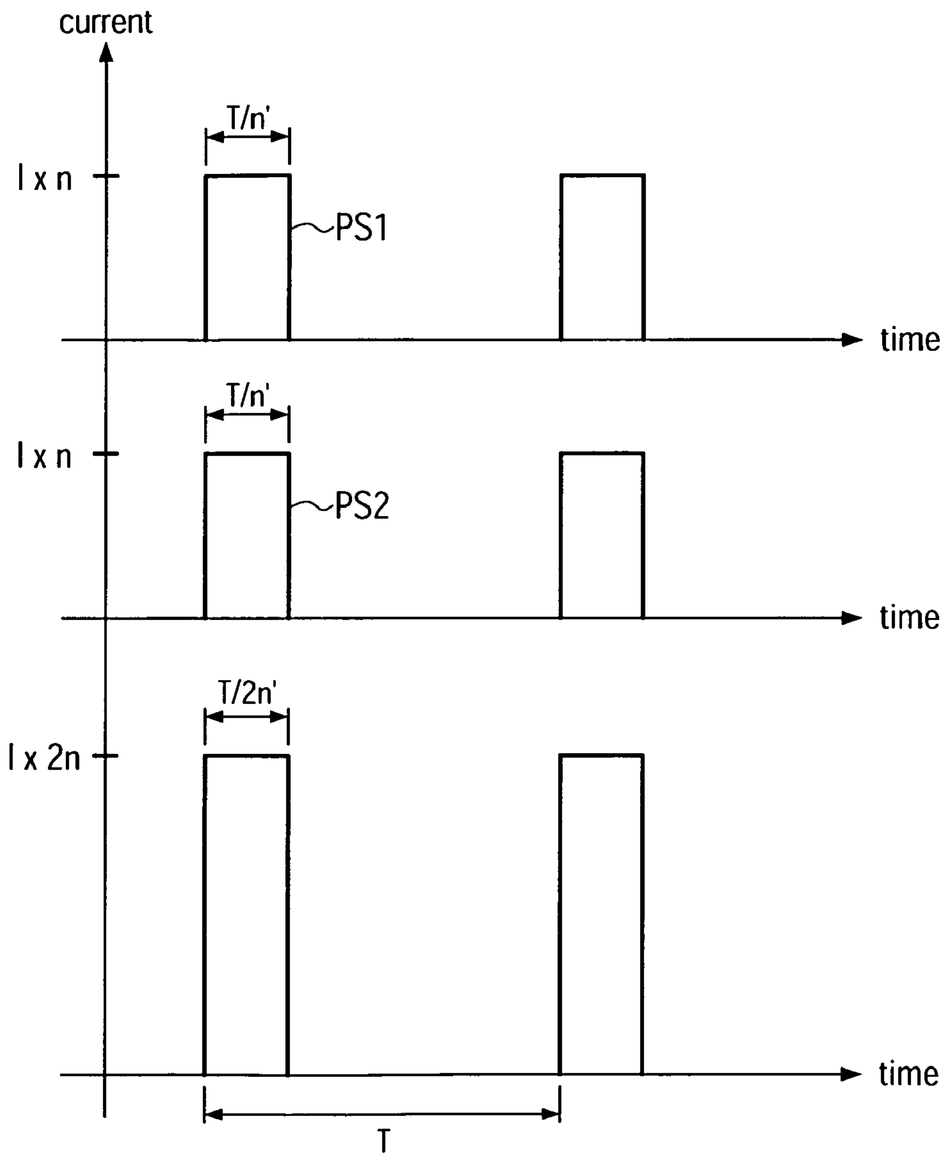

FIG. 5

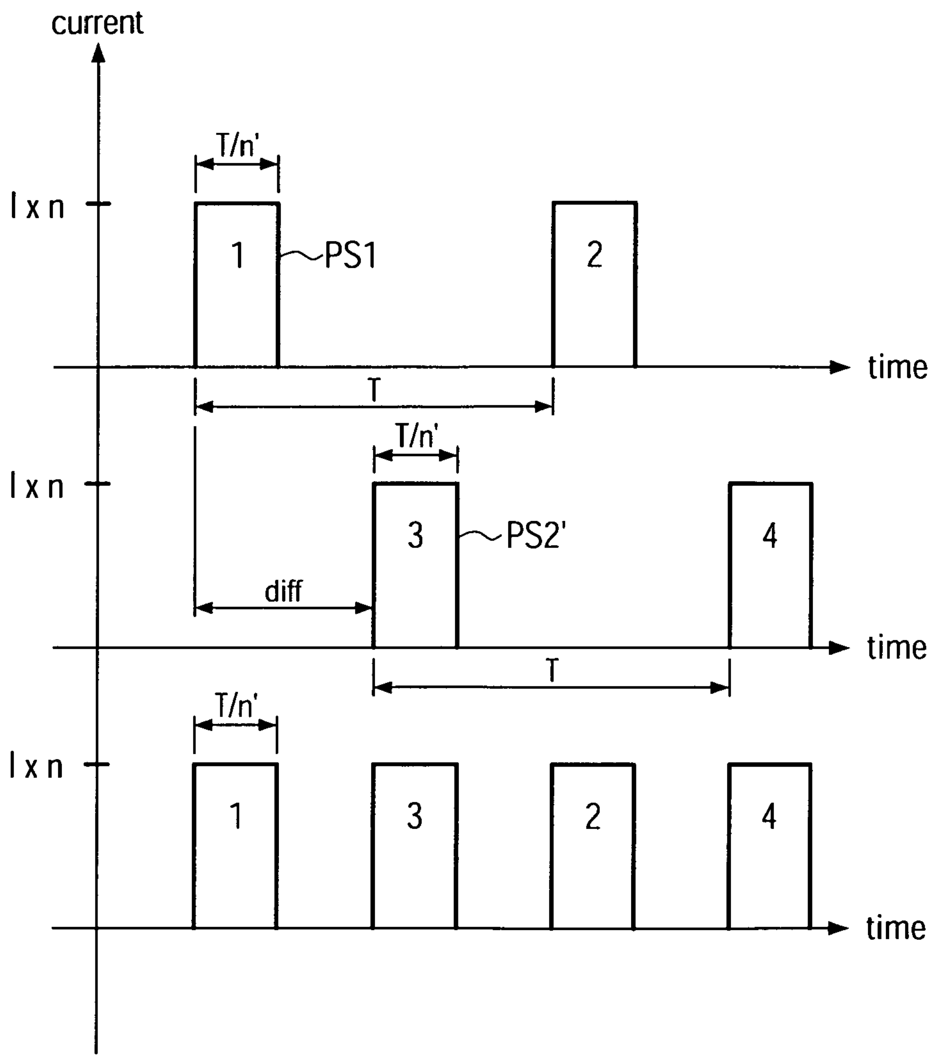
current
T/n'
I x n
1
PS1
2
time
T
T/n'
I x n
3
PS2'
4
diff
time
T
T/n'
I x n
1
3
2
4
time

FIG. 6

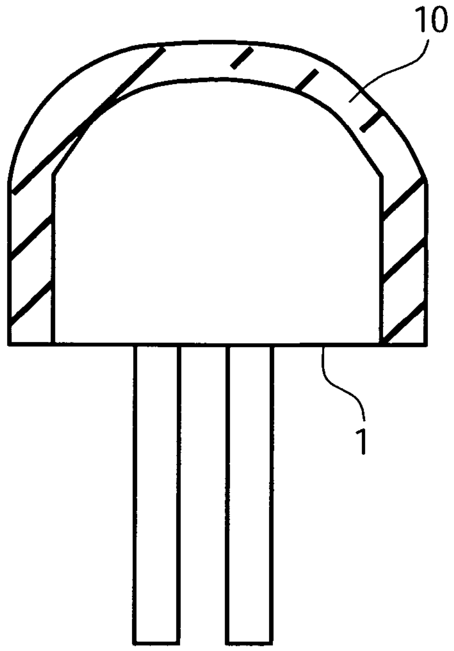

FIG. 7

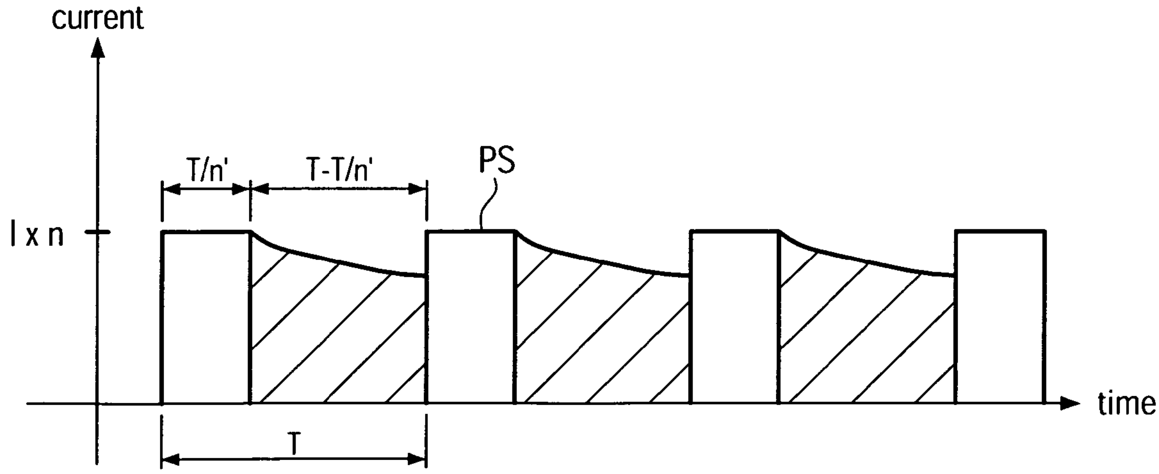

FIG. 8

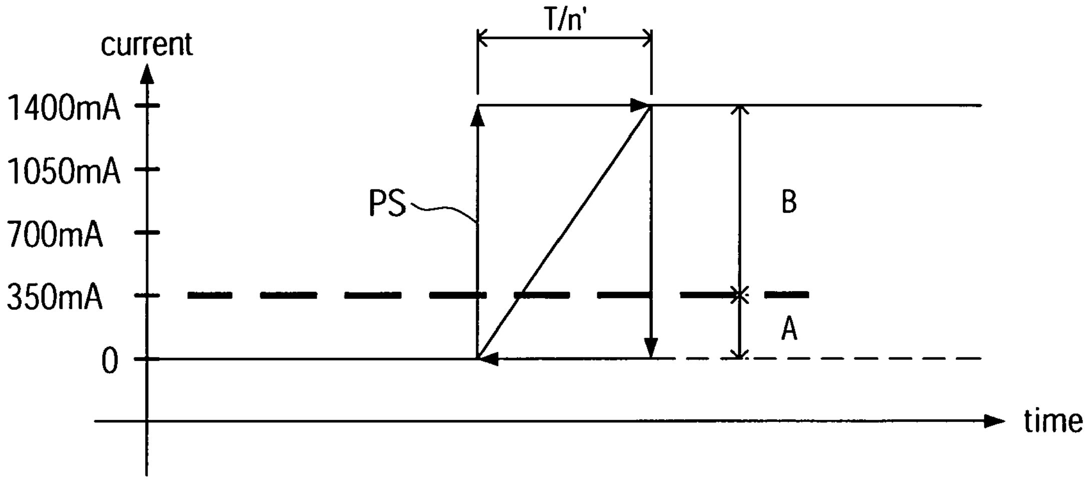

FIG. 9

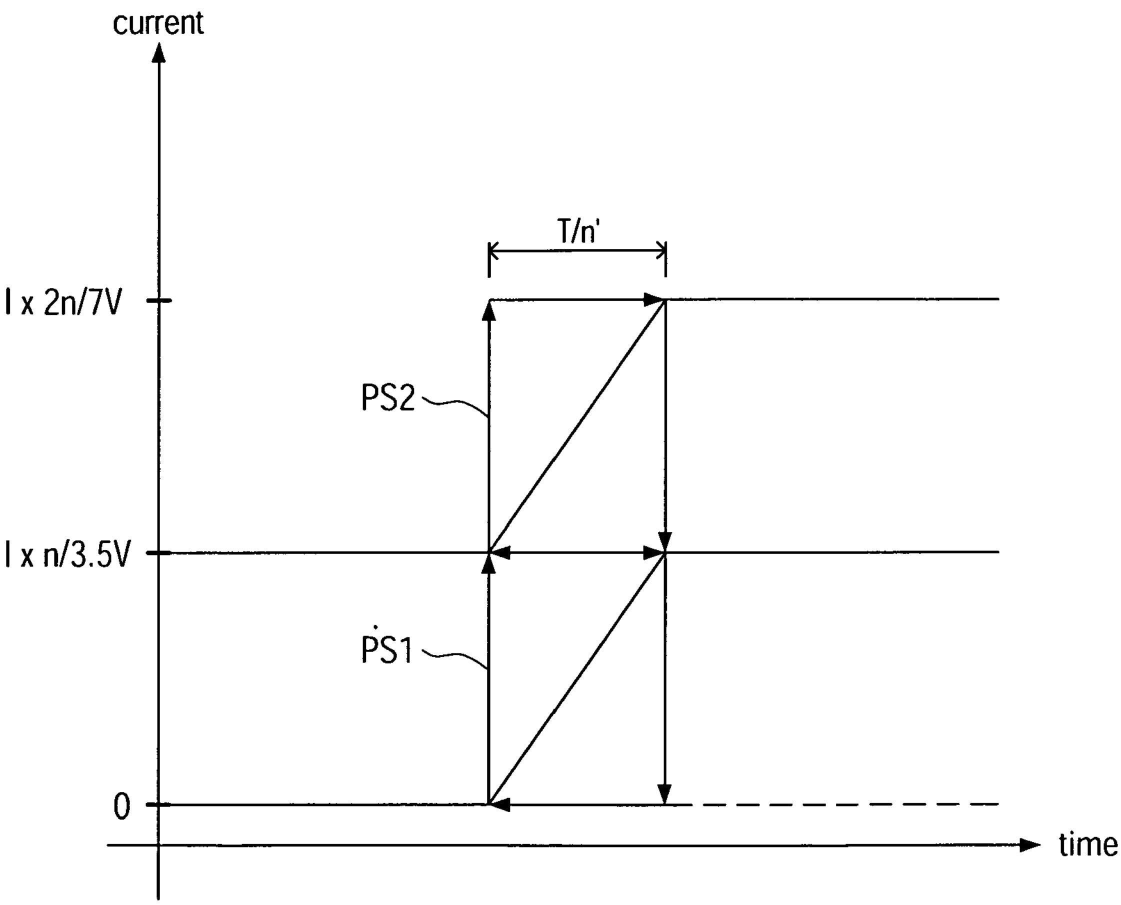

FIG. 10

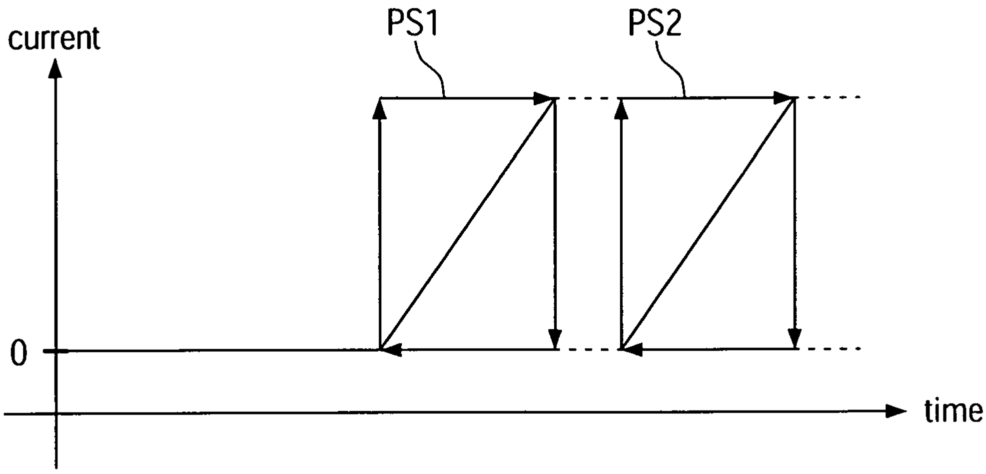

FIG. 11

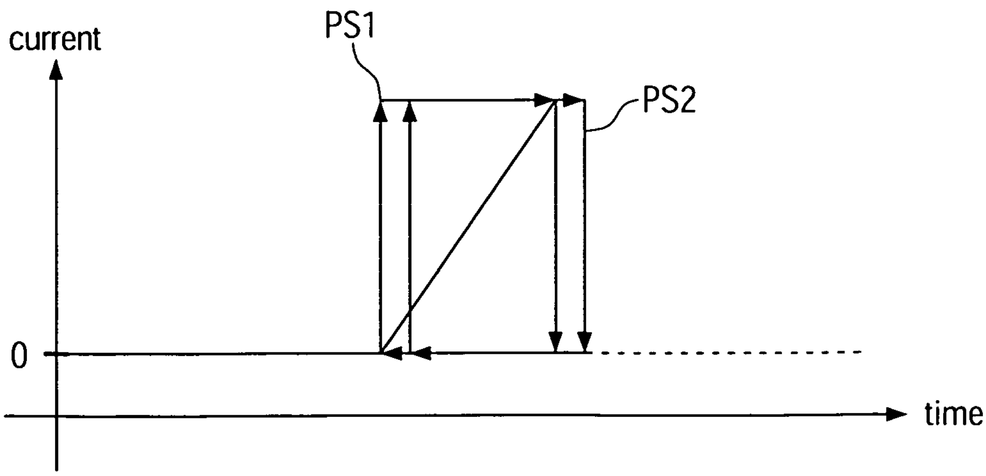

FIG. 12

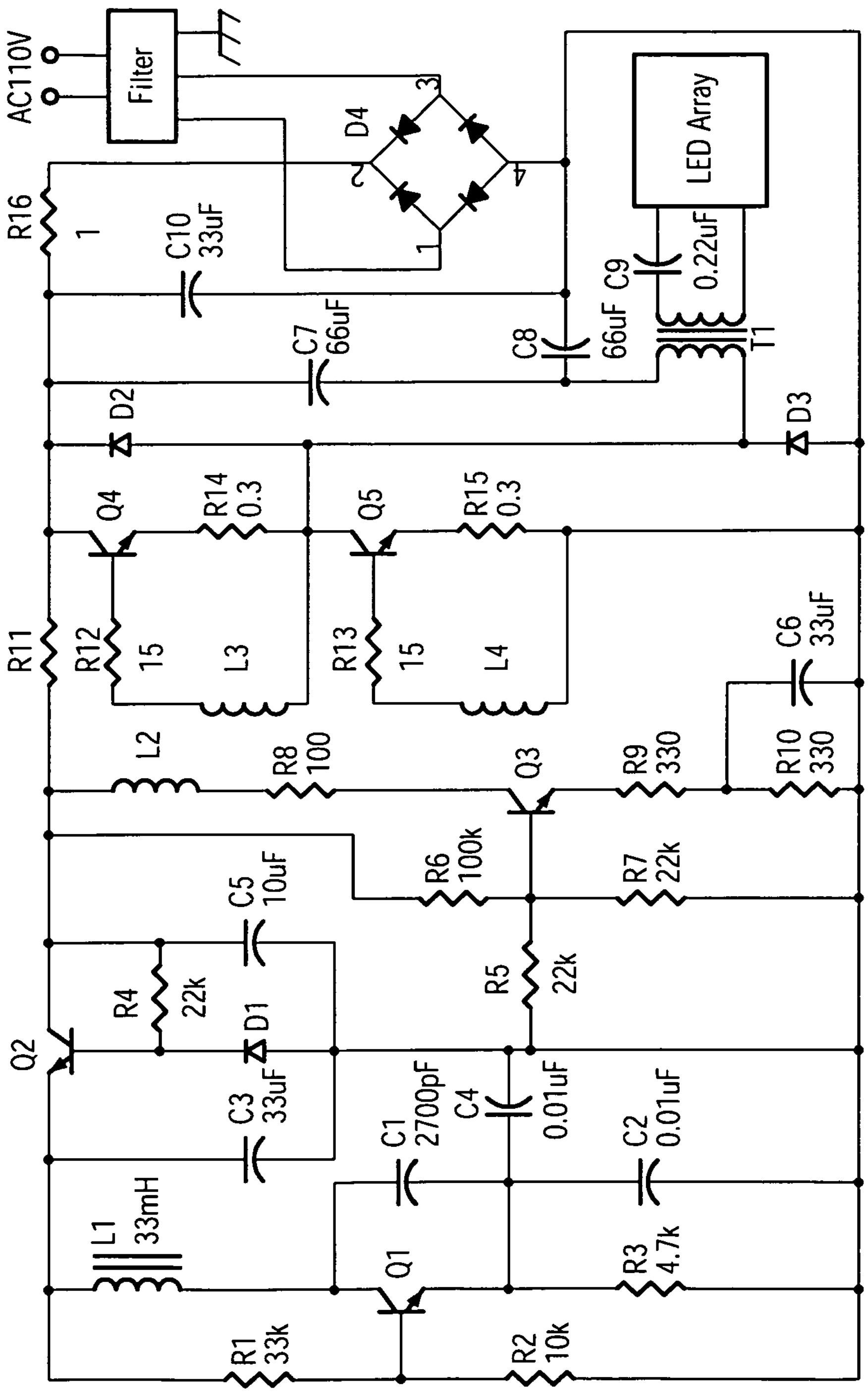
AC110V
Filter
D4
1
2
3
4
R16
1
C10
33uF
C7
66uF
C8
66uF
C9
0.22uF
LED Array
T1
D2
D3
Q4
R14
0.3
Q5
R15
0.3
R11
R12
15
L3
R13
15
L4
C6
33uF
L2
R8
100
Q3
R9
330
R10
330
R6
100k
R7
22k
C5
10uF
R4
22k
D1
Q2
R5
22k
C3
33uF
C1
2700pF
C4
0.01uF
C2
0.01uF
L1
33mH
Q1
R3
4.7k
R1
33k
R2
10k

FIG. 13

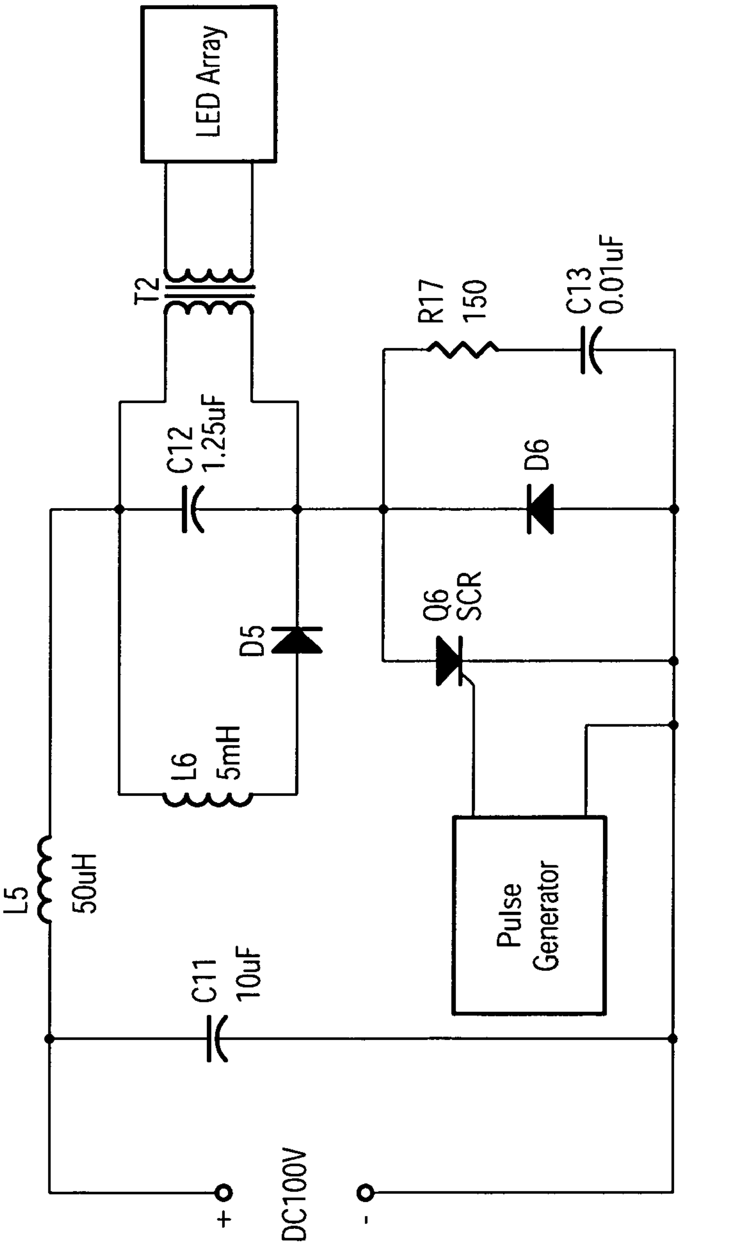
LED Array
T2
R17
150
C13
0.01uF
C12
1.25uF
D6
D5
Q6
SCR
L6
5mH
L5
50uH
Pulse
Generator
C11
10uF
+
DC100V
-

FIG. 14

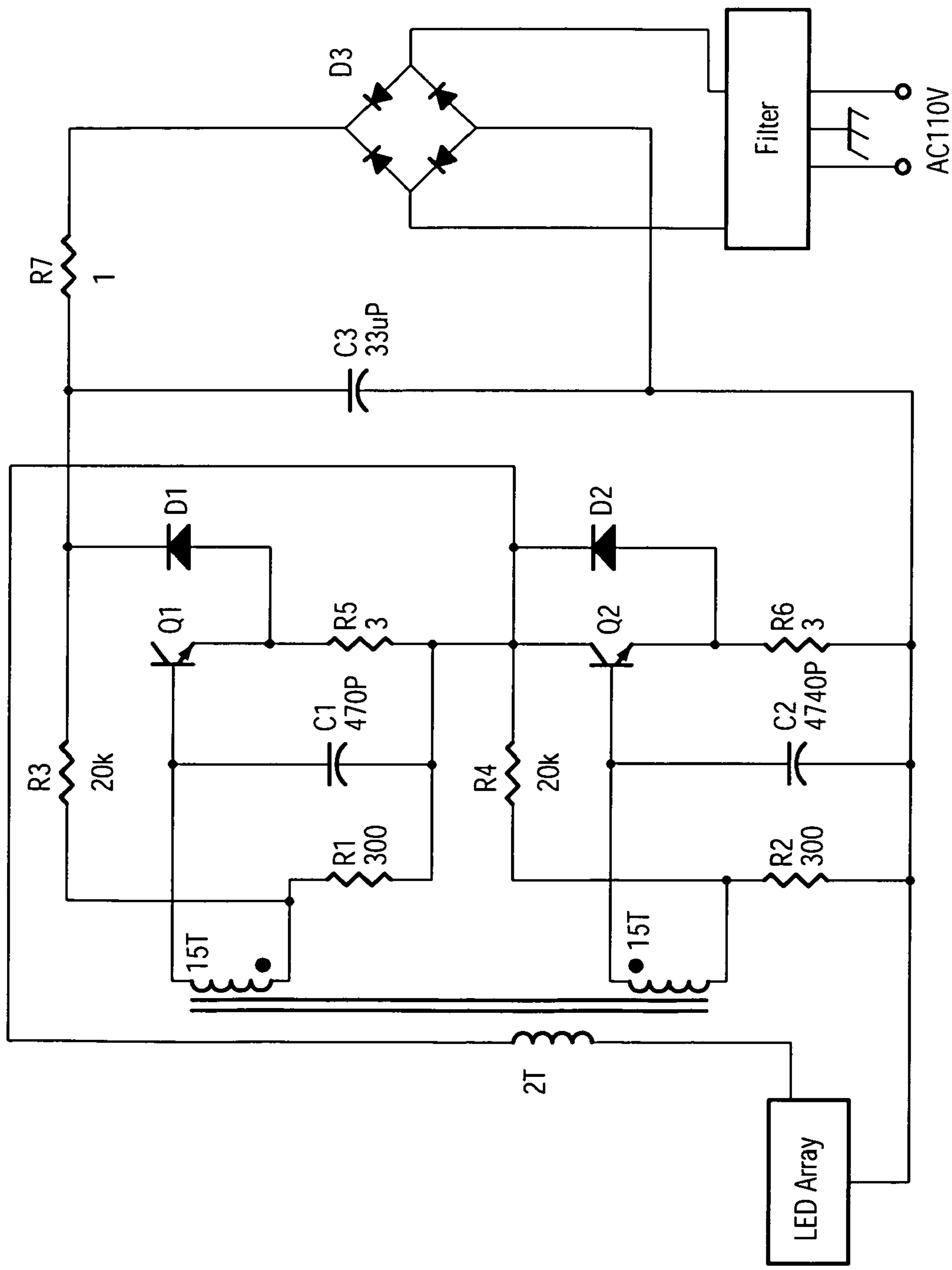
D3
R7
1
Filter
AC110V
C3
33uP
D1
D2
Q1
R5
3
Q2
R6
3
C1
470P
C2
4740P
R3
20k
R4
20k
R1
300
R2
300
15T
15T
2T
LED Array

FIG. 15

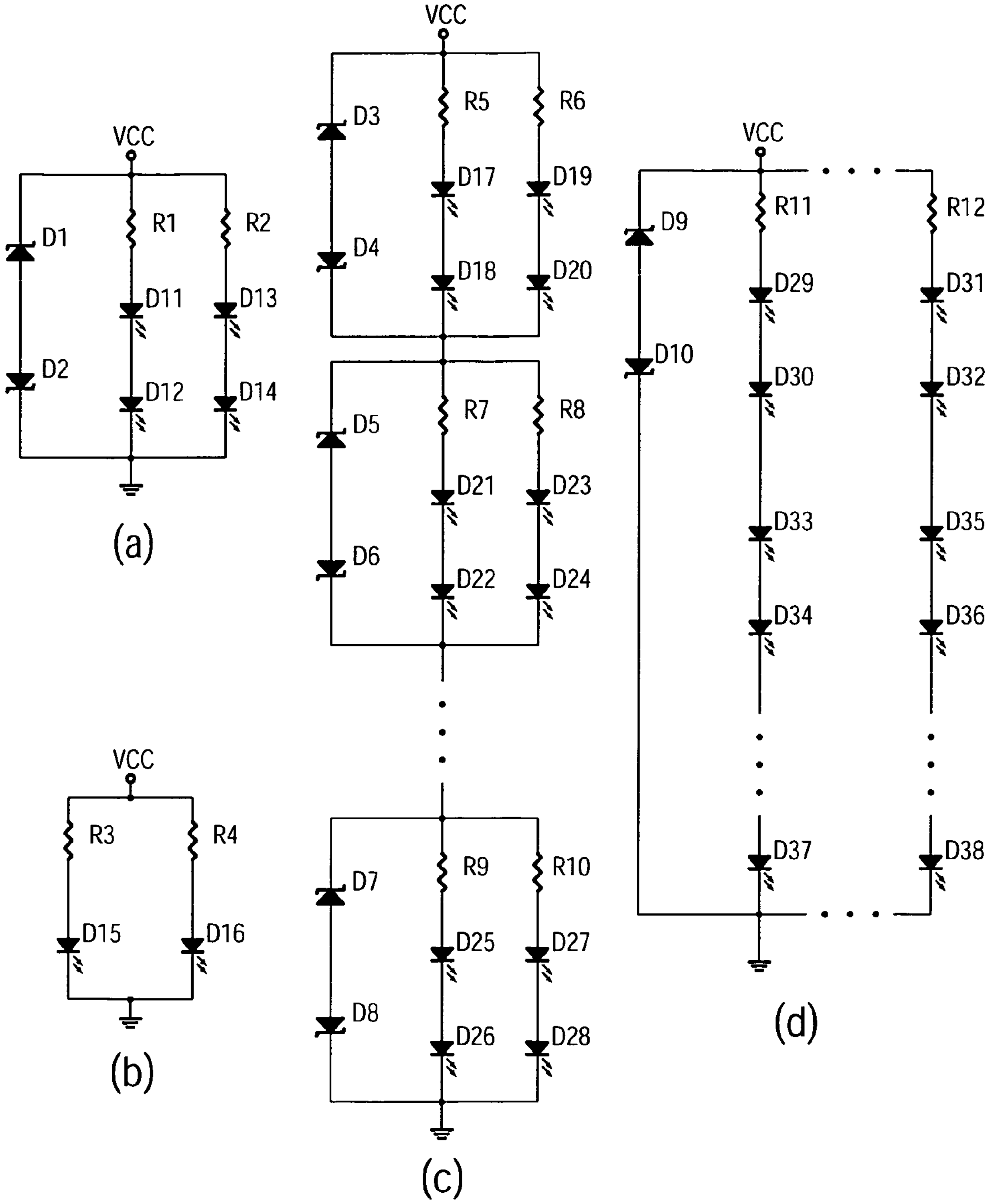
VCC
D1
R1
R2
D11
D13
D2
D12
D14
(a)
VCC
R3
R4
D15
D16
(b)
VCC
D3
R5
R6
D17
D19
D4
D18
D20
D5
R7
R8
D21
D23
D6
D22
D24
D7
R9
R10
D25
D27
D8
D26
D28
(c)
VCC
D9
R11
R12
D29
D31
D10
D30
D32
D33
D35
D34
D36
D37
D38
(d)

FIG. 16

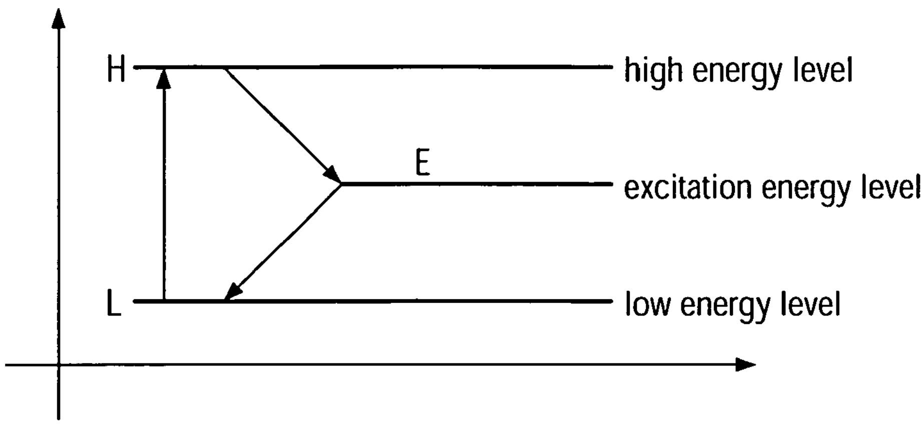
H
high energy level
E
excitation energy level
L
low energy level

FIG. 17

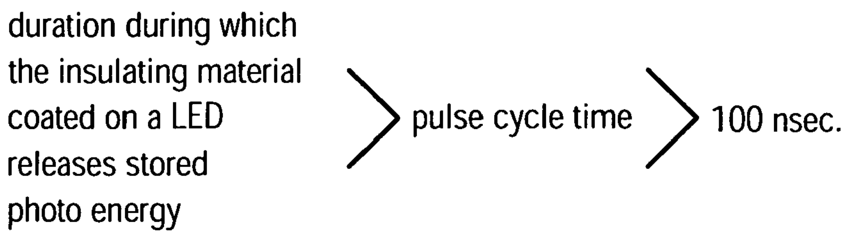
duration during which the insulating material coated on a LED releases stored photo energy
pulse cycle time
100 nsec.

FIG. 18

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 07 11 2349

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	US 6 028 694 A (SCHMIDT GREGORY W [US]) 22 February 2000 (2000-02-22) * the whole document *	1-10	INV. H05B33/08
A	WO 2007/020556 A (PHILIPS INTELLECTUAL PROPERTY [DE]; KONINKL PHILIPS ELECTRONICS NV [NL]) 22 February 2007 (2007-02-22) * the whole document *	1-10	
T	GB 2 408 315 A (RADIANT RES LTD [GB]) 25 May 2005 (2005-05-25) * page 7, last paragraph - page 8, paragraph 2; figure 24 *	1	

TECHNICAL FIELDS SEARCHED (IPC)
H05B

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	25 October 2007	Ferla, Monica

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

3

EPO FORM 1503 03.82 (P04C01)

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 07 11 2349

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
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25-10-2007

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 6028694 A	22-02-2000	NONE	
WO 2007020556 A	22-02-2007	NONE	
GB 2408315 A	25-05-2005	NONE	

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82