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

(11) EP 0 948 241 A2

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
06.10.1999 Bulletin 1999/40

(51) Int Cl.[6]: H05B 33/08

(21) Application number: 99660053.2

(22) Date of filing: 25.03.1999

(84) Designated Contracting States:
AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU MC NL PT SE
Designated Extension States:
AL LT LV MK RO SI

(30) Priority: 30.03.1998 FI 980717

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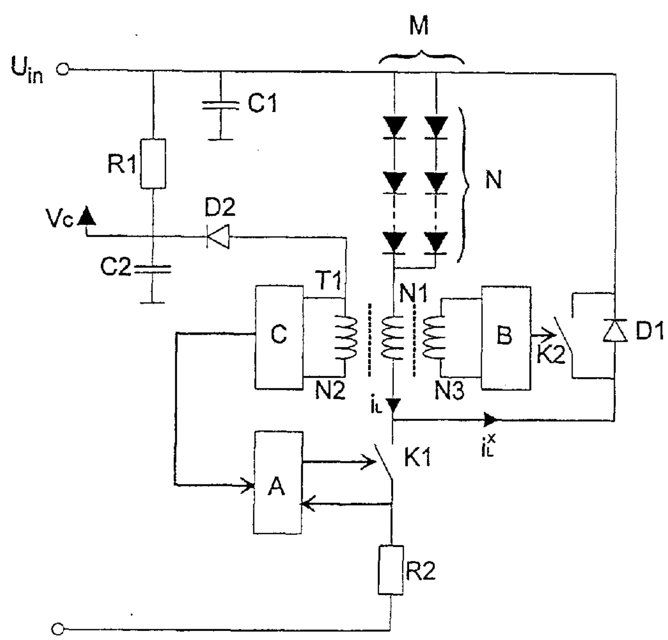
(54) Method and apparatus for supplying power to light emitting diodes

(57) The invention relates to a method and an apparatus for supplying power to light emitting diodes connected to a light emitting diode matrix (MN) comprising one or more parallel connected light emitting diodes or a series connection thereof. The method comprises repeated phases where the amount of current in the main circuit formed of a series connection of the light emitting diode matrix (MN), a switching element (K1) and an inductance (N1) is monitored, the main circuit is opened by the switching element (K1) when the current of the main circuit reaches a predetermined value, whereby the current starts flowing through a zero diode circuit formed of a zero diode (D1) arranged on a circuit, the amount of current in the zero diode circuit is monitored, and the main circuit is closed by the switching element (K1) when the zero diode circuit current reaches a predetermined value.

FIG. 1



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Description

BACKGROUND OF THE INVENTION

[0001] The invention relates to a method for supplying power to light emitting diodes connected to a light emitting diode matrix comprising one or more parallel connected individual light emitting diodes or a series connection thereof.

[0002] Light eniitting diodes are generally used in lighting fixtures, such as outdoor signs, commercial signs and the like. Connecting devices provided with a series resistor are conventionally used for operating light emitting diodes, whereby the arrangement causes unnecessary power loss. Particularly in battery-driven systems the series resistor significantly reduces the operating life as the battery capacity is limited. An example of such a battery-driven lighting system is the emergency exit lighting fixture, which should operate also when the mains voltage dies out.

[0003] Another conventional drawback with light emitting diodes using a series resistor is the dependence on a particular voltage level. The function of a series resistor is to arrange each voltage level to suit the use of light emitting diodes, in which case the fluctuation in voltage level causes problems for the light emitting diodes regarding their durability. An incorrect voltage level may provide such a high current that despite a bias resistor the light emitting diode may be broken. A too low supply voltage, in turn, is not adequate for a light emitting diode. As for the function of the light emitting diode, the voltage level has a commanding effect in conventional solutions provided with a series resistor.

BRIEF DESCRIPTION OF THE INVENTION

[0004] It is an object of the present invention to provide a method that avoids the above drawbacks and enables a more reliable power supply to light emitting diodes with a smaller power loss. The object is achieved with a method of the invention, characterized by comprising the steps of

> monitoring the amount of current in a main circuit formed of a series connection of a light emitting diode matrix, a switching element and an inductance,
> opening the main circuit by a switching element when the main circuit current reaches a predetermined value, whereby the current starts flowing through a zero diode circuit formed of a zero diode arranged on a circuit,
> monitoring the amount of current in the zero diode circuit, and
> closing the main circuit by the switching element when the current of the zero diode circuit reaches a predetermined value.

[0005] The method of the invention is based on the idea that an inductive component is connected in series with the light emitting diodes. The current of the light emitting diodes is monitored, and when the current exceeds a particular suitable predetermined limit the main circuit is opened, whereby the increase of light emitting diode current stops and the current starts flowing in a current loop forced by the inductive component. Then, as the energy stored in the inductive component decreases, the current of the light emitting diodes also decreases. When the current is reduced to a predetermined value, the main circuit can be closed again. The power supply method of the light emitting diodes of the invention has extremely low losses, since the use thereof does not require a series resistor for the light emitting diodes. During the use, the method can also be applied to varying voltage levels, and the method is therefore applicable to be used in demanding conditions and environments.

[0006] The invention also relates to a power supply apparatus of light emitting diodes comprising a light emitting diode matrix formed of one or more parallel connected individual light emitting diodes or a series connection thereof, characterized in that the power supply apparatus also comprises an inductance and a switching element, whereby a series connection of the light emitting diode matrix, the inductance and the switching element forms a main circuit of the power supply apparatus connected to a working voltage, a current monitoring block of the main circuit also arranged to control the switching element, a second current monitoring block arranged to convey a control signal to the block arranged to control the switching element, and a zero diode connected in parallel with the series connection of the inductance and the light emitting diode matrix in anti-parallel relation to the light emitting diodes of the light emitting diode matrix. By means of such an apparatus the advantages offered by a power supply method can be achieved with a simple, but reliable, structure.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] In the following the invention will be described in greater detail in connection with the preferred embodiments and with reference to the accompanying drawings, in which

> Figure 1 shows a schematic circuit diagram implementing a method of the invention, and
> Figure 2 is a schematic waveform showing a current of light emitting diodes of the method of the invention.

DETAILED DESCRIPTION OF THE INVENTION

[0008] Figure 1 shows a circuit implementing the method of the invention comprising a light emitting diode matrix MN including N light emitting diodes connected in series and M parallel connections thereof. One end of the light emitting diode matrix is connected to a positive supply voltage U_{in} and the other end is connected to an inductive component N1. According to an embodiment of the invention the inductive component N1 is a primary winding of a transformer T1. One electrode of the inductive component is further connected to a controllable switching element K1. This series circuit formed of the light emitting diode matrix MN, the inductive component N1 and the switching element K1 forms a main circuit of the power supply apparatus of the invention, to which the supply voltage U_{in} is connected. In the preferred embodiment of the invention, shown in Figure 1, the main circuit also comprises a series resistor R2. Figure 1 also shows a zero diode D1 of the circuit connected in the opposite direction in parallel with the series connection of the inductive component and the light emitting diode matrix.

[0009] Figure 1 also shows capacitors C1 and C2, the function of which is to operate as elements filtering and storing energy. The capacitor C2 in particular stores and filters the working voltage V_c of the auxiliary circuits needed in the apparatus. A resistance R1 of the circuit functions as a loading resistor, through which the working voltage needed by the auxiliary circuits is at first fed.

[0010] When the main circuit is connected to the supply voltage and when the switching element K1 is in a conducting state the current i_L flowing through the light emitting diode matrix starts increasing according to the equation $i_L = \frac{U_{in} - NV_L}{L} t_1$, where U_{in} is the amount of supply voltage, N is the number of light emitting diodes connected in series, V_L is the forward voltage of one light emitting diode, L is the inductance of the inductive component of the main circuit and t_1 is the time that the switch K1 is closed. The current described by the equation increases linearly with time as shown in Figure 2. In accordance with the method of the invention the amount of current i_L is monitored, and the switching element K1 opens the main circuit when the current reaches a predetermined value, which is the peak value of the current $\hat{I}_L$.

[0011] When the main circuit is opened, the current therein starts flowing in the zero diode circuit formed of the zero diode D1, the light emitting diode matrix MN and the inductive component N1. The energy stored in the inductive component enables the current flow in said circuit. The current of the zero diode circuit employs the following equation $i_L{}^x = \frac{NV_L - V_D}{L}(t_2 - t_1)$, where N is the number of light emitting diodes connected in series, V_L is the forward voltage of one light emitting diode, L is the inductance of the inductive component of the main circuit, t_1 is the time that the switch K1 is closed, t_2 is the time when the switch K1 will be closed and V_D is the forward voltage of the diode D1. Then the difference between the times t_2 and t_1 forms the time that the switch K1 is not conducting. The current $i_L{}^x$ decreases linearly, whereby the amount of current in the zero diode circuit is monitored in accordance with the invention and the main circuit is closed using the switching element K1 when said current has reached a predetermined limit. The predetermined limit can be defined, for example, so as to control the switch K1 when the current of the zero diode circuit dies out completely. The current may increase again in the main circuit, and said method phases are repeated in order to constantly operate the light emitting diodes.

[0012] The current of the light emitting diode matrix forms the saw-tooth wave, shown in Figure 2, whose rising edge is the current i_L and falling edge is the $i_L{}^x$. The average value of the current, or the average current I_{AVE}, can thus be geometrically interpreted as $I_{AVE} = ½\hat{I}_L$, i.e. the average current amount is half of the peak value of the current. The current of the light emitting diodes thus stays constant despite the variations in the working voltage. The amount of working voltage affects only the operating frequency of the switch K1, since the current i_L increases more rapidly into its peak value as the voltage U_{in} increases, but then again the amount of working voltage does not affect the amount or fall time of the current $i_L{}^x$. Hence, the light power produced by the light emitting diode matrix remains substantially constant irrespective of the level of the supply voltage. This is particularly important when the apparatus implementing the method is battery-driven, because as the capacity of the battery decreases its terminal voltage declines. Such a battery-driven apparatus may be, for example, an emergency exit lighting fixture, which is normally supplied by an electrical network, in which case the supply voltage of the apparatus can vary significantly. A notable advantage of the method of the invention is the independence of the available light power of the supply voltage level variations.

[0013] According to a preferred embodiment of the invention the current of the main circuit is monitored from the voltage that is over a series resistor R2 connected to the current circuit. Figure 1 shows how a current monitoring block A measures the voltage that is over the resistor R2. When the current of the main circuit reaches its peak value, then the voltage that is over the resistance R2 reaches the limit that is proportioned to the peak value of the current, and block A controls the switch K1 to open the main circuit. Current information about the zero diode circuit needed to close the main circuit is obtained in accordance with the preferred embodiment presented in Figure 1 through a secondary winding N2 of a transformer T1, when a primary winding N1 of the transformer is an inductive component connected to the main circuit. The winding N2 is connected to a current defining element C informing an element A arranged to control the switch K1 about the amount of current in the zero diode circuit in order to control the switch to a conducting state.

[0014] According to a preferred embodiment of the present invention the switch K2 can bypass the zero diode D1, in which case the zero diode circuit and at the same time the entire dissipation power of the switch can be minimized. In accordance with the embodiment it is observed that the current starts flowing in the zero diode circuit, whereafter the switching element K2 arranged in parallel with the zero diode D1 is switched to a conducting state. The amount of current is monitored as the current flows in the zero diode circuit, and as the current reaches a particular predetermined limit the switch K2 is switched from the conducting state. For this purpose, the apparatus implementing the method, shown in Figure 1, comprises as an inductive component N1 a transformer T1 whose secondary winding N3 provides current informa-tion for block B controlling the switch K2, on the basis of which the switch K2 is controlled. Block B changes the current information obtained from the winding to timing information, for example, using internal logic or trigger circuits. A great advantage provided by the power supply apparatus implementing the method of the invention is the low losses of the circuit which can further be reduced by utilizing the switch K2 bypassing the zero diode D1. As the dissipation power decreases in battery-driven apparatuses the operating time of the power supply apparatus correspondingly increases.

[0015] The circuit according to Figure 1 also comprises a diode D2 connected to the secondary winding N2 of the transformer T1. When the apparatus is operating the diode aims to supply current through the winding N2 of the transformer to the capacitor C2 maintaining the working voltage V_c of the auxiliary circuits of the circuit. Power is thus saved, as the supply voltage U_{in} does not need to be used directly through a resistor R1 in order to form the working voltage.

[0016] It is obvious for those skilled in the art that the basic idea of the invention can be implemented in various ways. The invention and its embodiments are thus not restricted to the above examples but can be modified within the scope of the attached claims.

Claims

1. A method for supplying power to light emitting diodes connected to a light emitting diode matrix (MN) comprising one or more parallel connected individual light emitting diodes or a series connection thereof, **characterized** by comprising the steps of

   monitoring the amount of current in a main circuit formed of the series connection of the light emitting diode matrix (MN), a switching element (K1) and an inductance (N1),
   opening the main circuit by a switching element (K1) when the main circuit current reaches a predetermined value, whereby the current starts flowing through a zero diode circuit formed of a zero diode (D1) arranged on a circuit,
   monitoring the amount of current in the zero diode circuit, and closing the main circuit by the switching element (K1) when the current of the zero diode circuit reaches a predetermined value.

2. A method as claimed in claim 1, **characterized** by comprising the steps of

   detecting the movement of the current to the zero diode circuit,
   switching the switch (K1) arranged in parallel with the zero diode (D1) to a conducting state,
   monitoring the amount of current in the zero diode circuit, and
   switching the switch (K2) arranged in parallel with the zero diode (D1) from the conducting state when the current of the zero diode circuit reaches a predetermined value.

3. A method as claimed in claim 2, **characterized** in that monitoring the current of the zero diode circuit comprises the step of
   monitoring the current of the zero diode circuit by using a winding (N3) of a transformer (T1) connected to the main circuit, the primary winding of the transformer (T1) being an inductance (N1) arranged to the main circuit.

4. A method as claimed in claims 1, 2 or 3, **characterized** in that monitoring the current of the main circuit comprises the step of
   monitoring the voltage over a resistor (R2) connected to the main circuit.

5. A method as claimed in any one of the preceding claims 1 - 4, **characterized** in that monitoring the current of the main circuit comprises the step of
   monitoring the current of the zero diode circuit by using a winding (N2) of the transformer (T1) connected to the main circuit, the primary winding of the transformer (T1) being the inductance (N1) arranged to the main circuit.

6. A power supply apparatus of light emitting diodes comprising a light emitting diode matrix (MN) formed of one or more parallel connected individual light emitting diodes or a series connection thereof, **characterized** in that the power supply apparatus also comprises an inductance (N1) and a switching element (K1), whereby a series connection of the light emitting diode matrix (MN), the inductance (N1) and the switching element (K1) forms a main circuit of the power supply apparatus connected to a working voltage (U_{in}), a current monitoring block (A) of the main circuit also arranged to control the switching element (K1), a second current monitoring block (C) arranged to convey a control signal to the block (A) arranged to control the switching element (K1), and a zero diode (D1) connected in parallel with the series connection of the inductance

(N1) and the light emitting diode matrix in anti-parallel relation to the light emitting diodes of the light emitting diode matrix.

7. A power supply apparatus as claimed in claim 6, **characterized** by further comprising a switching element (K2) and a control block (B) connected thereto arranged to control the switching element (K2) arranged in parallel with the zero diode (D1).

8. A power supply apparatus as claimed in claim 6 or 7, **characterized** by also comprising a transformer (T1) whereby the inductance (N1) connected to the main circuit is the primary winding of the transformer (T1) and the current defining block (C) is connected to a secondary winding (N2) of the transformer.

9. A power supply apparatus as claimed in claim 6, 7 and 8, **characterized** in that the inductance (N1) connected to the main circuit is the primary winding of the transformer (T1) and a control block (B) is con-nected to a secondary winding (N3) of the transformer.

10. A power supply apparatus as claimed in any one of the preceding claims 6 - 9, **characterized** in that the main circuit of the power supply apparatus also comprises a series resistor (R2).

FIG. 1

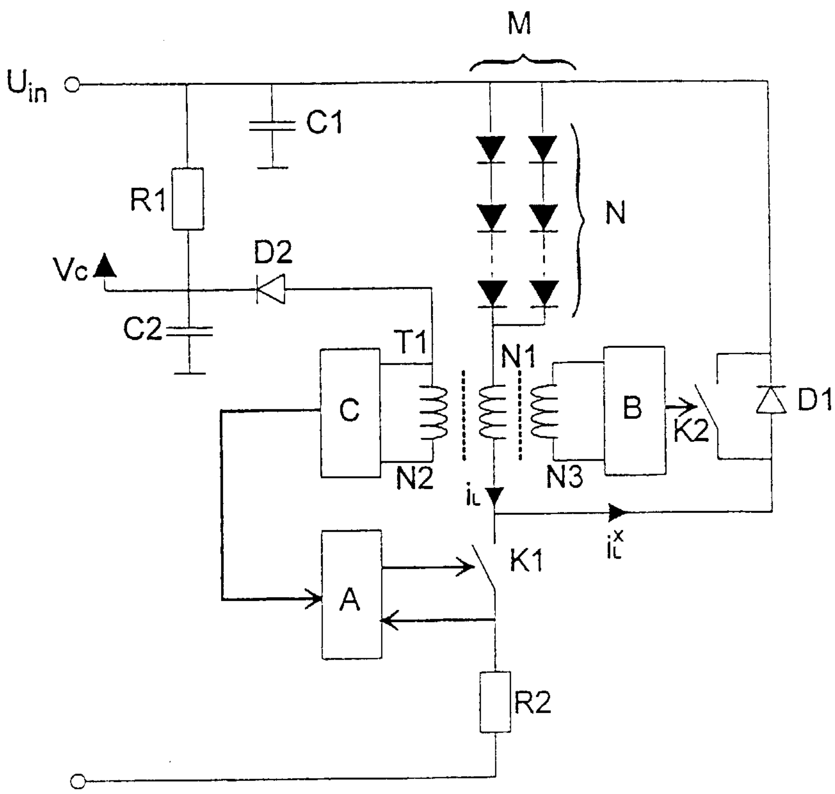
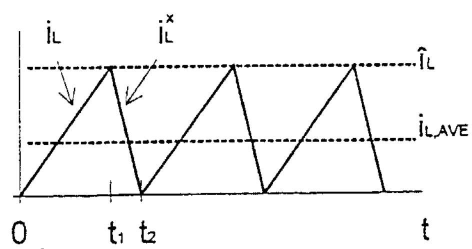

M
Uin
C1
R1
N
Vc
D2
C2
T1
N1
C
B
D1
K2
N2
N3
iL
iLx
K1
A
R2

FIG. 2


iL
iLx
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0
t1
t2
t