Abstract:

CONSTANT CURRENT PULSE WIDTH MODULATION DRIVING CIRCUIT FOR LIGHT EMITTING DIODE

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CONSTANT CURRENT PULSE WIDTH MODULATION DRIVING CIRCUIT FOR LIGHT EMITTING DIODE

Technical Field

The present invention relates to a constant current driving circuit for driving a constant current in the form of a Pulse Width Modulation (hereinafter referred to as "PWM") current (hereinafter referred to as "PWM constant current"), and a Light Emitting Diode (hereinafter referred to as "LED") driving circuit for conducting a constant current PWM control by using the same. More particularly, the present invention relates to a constant current driving circuit for driving a PWM constant current, and an LED driving circuit for conducting a constant current PWM control by using the same, which are designed to control an optical output, from in a plurality of LED arrays, and simultaneously enhance color reproducibility in such a manner that, in supplying the LED arrays with a constant current, the constant current driving circuit is connected in series to the LED arrays and regulates a current flowing through the LED arrays to be a constant current, the LED arrays are supplied with a stable voltage equal to or greater than the forward voltage of the LED arrays irrespective of a change in an input voltage by using a switching converter, which is a switching-type power
converting circuit, so as to reduce power consumption of the constant current driving circuit itself, a voltage above a certain voltage level is not applied to the constant current driving circuit, and the magnitude of a forward current flowing in the LED arrays is controlled in a perfect square wave PWM scheme.

Background Art

With the development of electronic communication technologies, most electronic communication appliances show a tendency to be more and more reduced in size and weight. Further, as the age of multimedia has arrived, visual information such as an image and a moving picture, rather than simple information such as a voice and a text is in the spotlight. Therefore, most recently released electronic communication appliances are provided with a display unit through which information can be visually displayed.

Until recently, a high-vacuum electron tube called a Cathode Ray Tube (hereinafter referred to as "CRT") has been used as a display unit. The CRT is a display unit which creates visible images by using cathode rays, that is, electrons emitted from a cathode in vacuum. However, it is hard to make it a small size and a light weight due to its structural features, and thus the CRT can not meet such
recent trend.

In addition to the CRT, display units, including a memory-type display device, a plasma display device, an LCD (Liquid Crystal Display), an ELD (Electro-Luminescence Display), an LED, an ECD (Electro Chromic Display) and the like, have recently come into the spotlight. These display units other than the CRT are under rapid development because they can be reduced in terms of size and weight.

Among such display units, the LED has superior energy-saving effect, as compared with light sources of the other above-mentioned display units, and can be semi-permanently used, with these features, the LED is recognized as a next-generation light source. Meanwhile, since the low luminance handicap of the LED has recently been considerably improved, the LED application market is broadening out to all fields of industry.

Further, the LED has recently been used as a main light source of mobile devices, such as a cellular phone, etc. Besides, the LED is used as the main light source of a hand-held appliances, for example, a cellular phone, a digital camera, a PDA (Personal Digital Assistant) and so forth. Further, a white LED using R (Red), G (Green) and B (Blue) colors is used as the back light source of a display according to the colorization of a mobile appliance keypad, and thus there is a great rush for the white LED.
Further, research and development is being vigorously conducted to substitute a CCFL (Cold Cathode Fluorescent Lamp) or an EEFL (External Electrode Fluorescent Lamp), commonly and frequently used as the back light source of an LCD panel, by an LED array in which a plurality of LEDs are connected in series or in series-parallel.

FIG. 1 is a conceptual view schematically illustrating a common LED back light unit.

The common LED back light unit includes a color/temperature sensor 120 for detecting the color and temperature of light emitted from a set of a plurality of LEDs of R, G and B colors, that is, an LED panel 110, a color controller 130 for delivering a PWM control signal to a constant current driver 140 through a series of feedback controls in order to control an output color by controlling the LEDs of R, G and B colors according to the detected color and temperature from the color/temperature sensor 120, and the constant current driving circuit 140 which, if receiving the PWM control signal, supplies the LED panel 110 with a square wave PWM constant current, defined by the control signal, to thereby drive the plurality of LEDs.

In addition, when special lighting, scene lighting, general lighting, etc. are to be implemented using the above-mentioned LED panel 110, in order to equalize light emitted from the LED panel 110 and control a color,
temperature and a color luminance, a current flowing through the LED panel 110 must be controlled in such a manner as to be a certain magnitude of constant current. Further, for the constant current control, it is preferred to control a current, flowing through the LED panel 110, in a PWM control scheme. In this way, a circuit for driving an LED while controlling a current in a PWM scheme such that a constant current can flow in the LED panel 110 is called a constant current driving circuit.

FIG. 2 is a circuit diagram illustrating an LED driving circuit employing a common linear control scheme.

The LED driving circuit employing a common linear control scheme includes an input DC power supply (Vin) 210, a transistor (Q) 220, an LED array 230, a sensing resistor (Rs) 240 and an amplifier (A) 250.

The input DC power supply 210 supplies a DC voltage as an operation power source of the LED driving circuit. The transistor 220 is connected to the input DC power supply 210, connected to the amplifier 250 by its base, and connected to the LED array 230. The transistor 220 is a device for controlling a large collector current by using a small base current, and controls a current output to an emitter, that is, a forward current (If) corresponding to a current flowing through the LED array 230, according to a current input from the base.
The LED array 230 is a bundle of a number of LED lines, each of which includes a plurality of serially-connected LEDs, that is, a set of LEDs connected in series or in series-parallel, and is connected in series to the transistor 220. Here, a current flowing through the LED array 230 is the forward current (If). The sensing resistor 240 is a resistor, having a minute resistance value, for generating a sensed voltage (Vs) which occurs as the forward current (If) flows in the LED array 230.

The amplifier 250 functions to maintain constant the amount of the forward current (If) flowing in the LED array 230 by comparing the amount of the forward current (If) flowing in the LED array 230, which has been converted into the form of the sensed voltage (Vs), with a reference voltage (Vf), and then amplifying a difference therebetween to adjust the amount of a current flowing in the base of the transistor 220.

The above-mentioned LED driving circuit employing a common linear control scheme has an advantageous in that it allows a highly accurate constant current to flow in the LED array 230 and can reduce an error range. The LED driving circuit employing a common linear control scheme has a further advantage in that if an on/off control is conducted while the base of the transistor 230 is connected to any switching circuit, the forward current (If) flowing
in the LED array 230 can be accurately controlled during a rapid switching time.

However, since if there is a large voltage difference between an input DC voltage input into the transistor 220 and a forward voltage (Vf) generated in the LED array 230, power corresponding to the product of the forward current (If) flowing in the LED array 230 and the both-end voltage of the transistor 220 is consumed, the LED driving circuit employing a common linear control scheme has a disadvantage in that efficiency is significantly lowered when the number of LEDs connected to the LED array 230 is small and thus the forward voltage (Vf) becomes lower than the fixed input DC voltage (Vin). In order to improve this disadvantage, there is used an LED driving circuit using a switching scheme in which the flowing forward current (If) is controlled using a switching converter in place of the transistor 220.

FIG. 3 is a circuit diagram illustrating an LED driving circuit employing a common switching scheme.

The LED driving circuit employing a common switching scheme is similar to the LED driving circuit employing a common linear control scheme, which has been described through FIG. 2, except that the forward current (If) is controlled not using the transistor 220 or a circuit consisting of a series of transistors, as described in FIG. 2, but using a
switching converter 310 in place of the transistor 220.

Further, an output capacitor (Co) 320 for suppressing the ripple phenomenon of an output voltage output from the switching converter 310 is added. Here, the switching converter may be implemented by a commonly used non-isolation type step-down or step-up converter, but other isolation types of converters as well as other non-isolation types of converters may also be used as the switching converter 310.

If the amplifier 250 compares the amount of the forward current (If) flowing in the LED array 230, which has been converted into the form of the sensed voltage (Vs), with the reference voltage (Vf), and then amplifies a difference therebetween to apply the amplified voltage difference to a feedback control circuit of the switching converter 310, the feedback control circuit adjusts the on/off time ratio of a switching device within the switching converter 310, that is, the duty ratio of a PWM control, to thereby regulate the amount of an output current.

In contrast with the LED driving circuit employing a common linear control scheme, which has been describe through FIG. 2, the above-mentioned LED driving circuit employing a common switching scheme can obtain an improvement in efficiency by not using the transistor 220
of the linear control scheme, but transferring energy in a switching scheme through various devices such as a switching device, an inductor, a transformer and the like. However, the LED driving circuit employing a common switching scheme has a disadvantage in that although much switching ripple is contained in a current flowing in the LED array 230 due to the switching ripple of an output voltage of the switching converter 310, it cannot completely reduce the magnitude of the ripple of the forward current (If).

FIG. 4 is an exemplary view illustrating the waveform of the forward current (If) output from the LED driving circuit employing a common switching scheme.

If it is assumed that the forward current (If) flowing through the LED array 230 is controlled to a frequency of around 600Hz by using a PWM control in the LED driving circuit employing a common switching scheme, then the waveform of the forward current (If) is output as illustrated in FIG. 4. In FIG. 4, values of the forward current (If) are plotted according to time (t). Here, "Ice" denotes the average value of the forward current (If), "D" denotes a switching duty, and "T" denotes a switching period.

As illustrated in FIG. 4, although the waveform of the forward current (If) exhibits a square waveform in the
LED driving circuit employing a common switching scheme, the forward current (If) contains much switching ripple, which may have a bad effect on the precise control of an LED. Further, if a switching duty ratio is reduced, then the square waveform does not appear.

FIG. 5 is an exemplary view illustrating the waveform of the forward current (If) when a switching duty ratio is reduced.

If the switching converter 310 is controlled by reducing a switching duty ratio in the forward current (If) as illustrated in FIG. 4, the waveform of the forward current (If) is affected by an inductor or a transformer within the switching converter 310, and thus a rising time and a falling time in the waveform become relatively longer, as compared with those before reducing the switching duty ratio. On this account, there is a problem in that the waveform of the forward current (If) is not an accurate square waveform, and thus it is difficult to control an LED. Further, there is another problem in that when a PWM control is conducted in the 600Hz band by using the switching converter 310, audible noise is generated in electrical components constituting the switching converter 310, which has a bad influence on product reliability.

Disclosure of the Invention
Accordingly, the present invention has been made to solve the above-mentioned problems occurring in the prior art, and an object of the present invention is to provide a constant current driving circuit for driving a PWM constant current, and an LED driving circuit for conducting a constant current PWM control by using the same, which are intended to control an optical output, generated in a plurality of LED arrays, and simultaneously enhance color reproducibility in such a manner that, in supplying the LED arrays with a constant current, the constant current driving circuit is connected in series to the LED arrays and controls a current flowing through the LED arrays to be a constant current, the LED arrays is supplied with a stable voltage equal to or greater than the forward voltage of the LED arrays irrespective of a change in an input voltage by using a switching converter, which is a switching-type power converting circuit, so as to prevent power consumption from being caused by the constant current driving circuit, a voltage above a certain voltage level is not applied to the constant current driving circuit, and the magnitude of a forward current flowing in the LED arrays is controlled in a perfect square wave PWM scheme.

In order to accomplish this object, in accordance with an aspect of the present invention, there is provided
an LED driving circuit for conducting a PWM control, which supplies a plurality of LEDs with a constant current, the LED driving circuit including: an input DC power supply for supplying a DC voltage; a switching converter, connected in series to the input DC power supply, for being supplied with the DC voltage from the input DC power supply, converting the DC voltage into an output voltage \( (V_o) \) in a switching scheme, the output voltage \( (V_o) \) corresponding to a voltage for driving the plurality of LEDs, which is equal to or greater than a certain voltage level, and delivering the converted output voltage \( (V_o) \); an LED array unit connected in series to the switching converter, and including the plurality of LEDs connected in series or in series-parallel, each of which flows a forward current \( (I_f) \) therethrough to emit light if the output voltage \( (V_o) \) is delivered thereto from the switching converter; a constant current driver, connected in series to the LED array unit, for controlling the forward current \( (I_f) \) in a linear control scheme in such a manner as to be the constant current; and a feedback controller, connected to one or more of a first stage between the switching converter and the LED array unit and a second stage between the LED array unit and the constant current driver, for controlling the switching converter in such a manner that the output voltage \( (V_o) \) is equal to or greater than at least an
forward voltage \((V_f)\) of the LED array unit.

In accordance with another aspect of the present invention, there is provided a constant current driving circuit for driving a PWM constant current, which supplies a plurality of LEDs with the constant current in an LED driving circuit for supplying the plurality of LEDs with the constant current to drive the plurality of LEDs, the constant current driving circuit including: a sensing resistor for sensing a forward current \((I_f)\) flowing through the plurality of LEDs; an amplifier, connected to between a transistor and the sensing resistor, for sensing the forward current \((I_f)\), flowing in the plurality of LEDs and the transistor, as a sensed voltage generated by the sensing resistor, and then amplifying a difference between the sensed voltage and a reference voltage \((V_{ref})\) to deliver an amplified voltage value; a constant current PWM on/off driving circuit for receiving the amplified voltage value from the amplifier and adjusting a base current of the transistor, thereby flowing the constant current in the plurality of LEDs which are connected in series to the transistor; and the transistor, connected to the plurality of LEDs and connected to the constant current PWM on/off driving circuit, for flowing the forward current in the plurality of LEDs according to a control of the constant current PWM on/off driving circuit.
In accordance with yet another aspect of the present invention, there is provided an LED driving circuit for driving a PWM constant current by using an AC power supply, which supplies a plurality of LEDs with the constant current to drive the plurality of LEDs, the LED driving circuit including: an input AC power supply for supplying an AC voltage; a PFC, connected in series to the input AC power supply, for being supplied with the AC voltage from the input AC power supply, reducing a harmonic distortion of the AC voltage, and converting the AC voltage into a DC voltage; a smoothing capacitor for receiving the AC voltage from the PFC, accumulating therein charges, and then delivering a constant DC voltage; an isolation type switching converter, connected in series to the PFC and connected in parallel to the smoothing capacitor, for receiving the constant DC voltage, converting the constant DC voltage into a voltage which is equal to or greater than a reference voltage (Vref) to be applied to the plurality of LEDs, and delivering an output voltage (Vo); an LED array unit connected in series to the isolation type switching converter, and including the plurality of LEDs connected in series or in series-parallel, each of which flows a forward current (If) therethrough to emit light if the output voltage (Vo) is delivered thereto from the isolation type switching converter; a constant current
driver, connected in series to the LED array unit, for controlling the forward current (If) to be the constant current; and a feedback controller, connected to one or more of a first stage between the switching converter and the LED array unit and a second stage between the LED array unit and the constant current driver, for controlling the switching converter in such a manner that the output voltage (Vo) is equal to or greater than at least an forward voltage (Vf) of the LED array unit.

**Brief Description of the Drawings**

The foregoing and other objects, features and advantages of the present invention will become more apparent from the following detailed description when taken in conjunction with the accompanying drawings in which:

- FIG. 1 is a conceptual view schematically illustrating a common LED back light unit;
- FIG. 2 is a circuit diagram illustrating an LED driving circuit employing a common linear control scheme;
- FIG. 3 is a circuit diagram illustrating an LED driving circuit employing a common switching scheme;
- FIG. 4 is an exemplary view illustrating the waveform of a forward current output from the LED driving circuit employing a common switching scheme;
FIG. 5 is an exemplary view illustrating the waveform of a forward current output from the LED driving circuit employing a common switching scheme when a switching duty ratio is reduced;

FIG. 6 is a circuit diagram illustrating an LED driving circuit for conducting a PWM control in accordance with a first preferred embodiment of the present invention;

FIG. 7 is a circuit diagram illustrating a constant current driving circuit for driving a PWM constant current in accordance with the first embodiment of the present invention;

FIG. 8 is an exemplary view illustrating the waveform of a PWM forward current of an LED which is controlled using the constant current driving circuit for supplying the LED with a PWM constant current in accordance with the first embodiment of the present invention; and

FIG. 9 is a circuit diagram illustrating an LED driving circuit for conducting a PWM control in accordance with a second preferred embodiment of the present invention.

Best Mode for Carrying Out the Invention

Reference will now be made in detail to preferred embodiments of the present invention, with reference to the
accompanying drawings. The same reference numerals are used to designate the same elements as those shown in other drawings. In the following description of the present invention, a detailed description of known configurations and functions incorporated herein will be omitted when it may make the subject matter of the present invention rather unclear.

FIG. 6 is a circuit diagram illustrating an LED driving circuit for conducting a PWM control in accordance with a first preferred embodiment of the present invention. The LED driving circuit for conducting a PWM control according to the first embodiment of the present invention includes the input DC power supply (Vin) 210, the switching converter 310 and the output capacitor (Co) 320, which have been described above through FIGS. 2 and 3. In addition to these constitutional elements, the LED driving circuit for conducting a PWM control according to the first embodiment of the present invention further includes an LED array unit 610, a constant current driver 620 and a feedback controller 630. In the following description, a repetitive description of the constitutional elements, which have been already described above through FIGS. 2 and 3, will be omitted.

The input DC power supply 210 is connected in series to the switching converter 310, and the output capacitor
320 is connected between the switching converter 310 and the LED array unit 610. The magnitude of a voltage of the input DC power supply 210 may be usually different from that of a forward voltage (Vf) of the LED array unit 610. Thus, the switching converter 310 functions to convert an output voltage (Vo) of the switching converter 310, which is applied to the LED array unit 610, into a voltage equal to or greater than the forward voltage (Vf) irrespective of the magnitude of the voltage of the input DC power supply 210. Further, since ripple including high-frequency ripple, which is caused by the PWM driving frequency of an output constant current, is formed in the voltage output from the switching converter 310, the output voltage is delivered to the LED array unit 610 while the ripple is suppressed through the output capacitor 320 or an additional high-frequency filter (not shown). That is, it is preferred to suppress the ripple through the output capacitor 320 or a high-frequency filter.

The LED array unit 610 according to the first embodiment of the present invention includes a number of LED arrays, in each of which a plurality of LEDs are connected in series, that is, is a set of LED arrays including a first LED array 612 to an nth LED array 614 which are connected in parallel. The LED array unit 610 is connected in series to the switching converter 310 and is
connected in parallel to the output capacitor 320, and thus if the output voltage (Vo) of the output capacitor 320 is applied, the plurality of LEDs are all driven to emit light of various colors therethrough.

The constant current driver 620 according to the first embodiment of the present invention is connected between the LED array unit 610 and the ground, operates in a linear control scheme to control the forward current (If), flowing through the LED array unit 610, in such a manner as to be a constant current, and if an on/off PWM waveform is externally applied thereto, on/off controls the base of the transistor 220 to form the waveform of the constant current in a square wave PWM waveform, thereby making the forward current (If) be a constant current of a perfect PWM square wave.

Further, the constant current driver 620 according to the first embodiment of the present invention includes a plurality of constant current driving circuits, that is, a first constant current driving circuit 622 to an nth constant current driving circuit 624. Here, the respective constant current driving circuits, that is, the first constant current driving circuit 622 to the nth constant current driving circuit 624, are connected in series to the first LED array 612 to the nth LED array 614 of the LED array unit 610 while corresponding one-to-one thereto, and
thus control the forward current (If) flowing through each LED array to be a constant current. This constant current driver 620 will be described in detail below through FIG. 7.

In addition, although the constant current driver 620 according to the first embodiment of the present invention may consist of a plurality of constant current driving circuit corresponding one-to-one to a plurality of LED arrays, and control a subordinate forward current of each LED array and thus the overall forward current to be a constant current, it may also control the forward current to be a constant current in such a manner that one constant current driving circuit controls subordinate forward currents of a plurality of LED arrays to be a constant current.

Although the constant current driver 620 is illustrated as being connected between the LED array unit 610 and the ground in FIG. 6, it may control the forward current (If) flowing through the LED array unit 610 to be a constant current while connected in series between the switching converter 310 and the LED array unit 610. However, the constant current driver 620 is preferably connected between the LED array unit 610 and the ground, as illustrated in FIG. 6. That is, if the constant current driver 620 is connected in series between the switching converter 310 and the LED array unit 610, it becomes
difficult to drive internal devices of the constant current

driver 620 because the reference potential of the constant
current driver 620 increases by a potential corresponding
to the output voltage (Vo), and thus various devices must
be used in order to solve this problem. Thus, such an
arrangement is not desirable in that it is difficult to
efficiently configure circuitry within the constant current
driver 620 and a problem of the impossibility of an
accurate constant current control occurs.

The feedback controller 630 according to the first
embodiment of the present invention, which is connected to
a first stage between the switching converter 310 and the
LED array unit 610, to a second stage between the LED array
unit 610 and the constant current driver 620, to the
switching converter 310, and to the constant current driver
620, respectively, supplies the LED array unit 610 with a
stable DC power independent of a change in an input DC
voltage (Vin) by controlling the switching converter 310
such that the output voltage (Vo) become any voltage set to
above the forward voltage (Vf) of the LED array unit 610,
and minimizes power consumption, occurring in the constant
current driver 620, by controlling the output voltage (Vo)
to be the sum of the forward current of the LED array unit
610 and an arbitrarily set voltage drop (Vd) of the
constant current driver 620.
That is, the feedback controller 630 according to the first embodiment of the present invention builds up the output voltage \( (V_o) \) of the switching converter 310 above at least the forward voltage \( (V_f) \) of the LED array unit 610 to satisfy the minimum necessary condition for driving the LED array unit 610, and yet adjusts the output voltage \( (V_o) \) of the switching converter 310 such that a voltage, which is arbitrarily set considering a bias voltage sufficient for operating the internal circuit of the constant current driver 620 and power consumption by the forward voltage \( (V_f) \), occurs through a voltage drop \( (V_d, \text{that is, } V_{dI} \text{ to } V_{dn}) \) of the constant current driver 620.

Further, although the feedback controller 630 may simultaneously sense the output voltage \( (V_o) \) of the switching converter 310 and the voltage drop \( (V_d) \) between both ends of the constant current driver 310 by being connected to both the first stage for sensing the output voltage \( (V_o) \) and the second stage for sensing the voltage drop \( (V_d) \), and control the switching converter 310 such that an arbitrarily set output voltage \( (V_o) \) and an arbitrarily set voltage drop \( (V_d) \) of the constant current driver 620 are formed, as illustrated in FIG. 6, it may also be connected to only one of both the stages to thereby sense only one of the output voltage \( (V_o) \) and the voltage drop \( (V_d) \) of the constant current driver 620 and feedback-
control the switching converter 310, thereby making it possible to enhance efficiency in the constant current driver 620.

In other words, when the feedback controller 630 is connected between the LED array unit 610 and the constant current driver 620 to sense only the voltage drop (Vd) of the constant current driver 620, it continually raises the output voltage (Vo) of the switching converter 310 through the feedback control because if the output voltage (Vo) of the switching converter 310 lies below the forward voltage (Vf) of the LED array unit 610, a current does not flow through the LED array unit 610 and thus no voltage is formed in the constant current driver 620. Accordingly, the feedback controller 630 raises the output voltage (Vo) by controlling the switching converter 310 such that the voltage drop (Vd) of the constant current driver 620 becomes an arbitrarily set voltage drop (Vd) of the constant current driver 620, so that it can solve drawbacks of the constant current driver 620 employing the linear control scheme.

With respect to this, if a PWM control is conducted in the constant current driver 620 to control the forward current (If) flowing in the LED array unit 610 to a PWM waveform of a square wave, the output voltage (Vo) of the switching converter 310 may rise because a certain portion
of the output voltage \((V_0)\) is applied to the constant
current driver 620 when the forward current \((i_f)\) does not
flow through the LED array unit 610, and in view of the
operation of the switching converter 310, its state shifts
from a loaded state to a loadless state.

Further, when the feedback controller 630 senses only
the output voltage \((V_0)\) of the switching converter 310, it
can minimize power consumption in the constant current
driver 620 by conducting a feedback control in such a
manner as to form an output voltage \((V_0)\) set corresponding
to the sum of a forward current \((i_f)\) of the LED array unit
610, which is predicted by the sum of forward currents of
individual LED devices, and a voltage drop \((V_d)\) of the
constant current driver 620, which is to be arbitrarily set.

Further, the feedback controller 630 according to the
first embodiment of the present invention not only
functions to minimize the voltage drop over the constant
current driver 620, but also serves to maintain constant a
voltage output from the switching converter 310 in order to
prevent the output voltage \((V_0)\) of the switching converter
310 from changing in the course of controlling a current
flowing in the LED array unit 610 to the PWM square
waveform in the constant current driver 620. Furthermore,
the feedback controller 630 according to the first
embodiment of the present invention also functions to
prevent abnormal operations or breakage due to a temperature, an overvoltage or an excess current occurring in the circuit.

FIG. 7 is a circuit diagram illustrating a constant current driving circuit for driving a PWM constant current in accordance with the first embodiment of the present invention.

The first constant current driving circuit 622 to the nth constant current driving circuit 624 of the constant current driver 620, which have been described above through FIG. 6, are configured as illustrated in FIG. 7. The first constant current driving circuit 622 to the nth constant current driving circuit 624 control forward currents flowing in the first LED array 612 to the nth LED array 614, respectively, but have the same constitutional elements. Thus, a description will be given below for only the nth constant current driving circuit 624 as illustrated in FIG. 7.

The constant current driving circuit for supplying a PWM constant current according to the first embodiment of the present invention, that is, the nth constant current driving circuit 624, includes an nth transistor (Qn) 710, an nth sensing resistor (Rn) 720, an nth amplifier (An) 730 and an nth constant current PWM on/off driving circuit 740, and is connected between the nth LED array 614 and the
ground. Although the nth constant current driving circuit 624 is illustrated as being connected in series between the nth LED array 624 and the ground, it may be connected in series between the output capacitor 320 and the nth LED array 624. However, the nth constant current driving circuit 624 is preferably connected in series between the nth LED array 624 and the ground, which has been already explained through FIG. 6, so a detailed description thereof will be omitted.

The nth transistor 710 is connected to the nth LED array 614 by its collector in the case of an NPN transistor or by its emitter in the case of a PNP transistor, connected to the nth constant current PWM on/off driving circuit 740 by its base, and connected to the nth sensing resistor 720 by its emitter in the case of an NPN transistor or by its collector in the case of a PNP transistor. The nth transistor 710 is a device for controlling a large collector current by using a small base current, and controls a current output to the emitter or collector, that is, a forward current (If) corresponding to a current flowing through the nth LED array 614, to be a constant current, according to a current input from the base.

The nth sensing resistor 720 is a device for forming an nth sensed voltage (Vn) which is generated by the
forward current \((I_f)\) flowing in the \(n\)th transistor 710 through the \(n\)th LED array 710. The \(n\)th sensed voltage \((V_n)\) is input into the \(n\)th amplifier 730, and the \(n\)th amplifier 730 allows a constant current having a certain magnitude to flow through the \(n\)th LED array 614 by amplifying a difference between the \(n\)th sensed voltage \((V_n)\) and a set reference voltage \((V_{\text{ref}})\) and controlling the base current of the \(n\)th transistor 710 by means of the \(n\)th constant current PWM on/off driving circuit 740.

The \(n\)th constant current PWM on/off driving circuit 740 consists of a series of circuits for adjusting the base current of the \(n\)th transistor 710 if the difference between the reference voltage \((V_{\text{ref}})\) and the sensed voltage sensed by the sensing resistor 720 is delivered to the \(n\)th constant current PWM on/off driving circuit 740, and conducts a series of operations for externally receiving an on/off PWM waveform and on/off controlling the \(n\)th transistor 710 in order to form the waveform of a constant current flowing in the LED array unit 610 into a square waveform.

Here, when the \(n\)th constant current PWM on/off driving circuit 740 does not externally receive an on/off PWM waveform, it does not form the constant current waveform into a constant current of a square wave PWM waveform. That is, the constant current of a square wave
PWM waveform is output only when the PWM on/off waveform is externally input into the nth constant current PWM on/off driving circuit 740, if necessary.

As stated above, the nth constant current driving circuit 624 can control the nth forward current (I_{fn}) flowing through the nth LED array 614 to be a constant current. In this way, the first constant current driving circuit 622 to the (n-1)th constant current driving circuit (not shown) also control the first to (n-1)th forward currents (I_{f1} to I_{fn-1}) flowing through the first LED array 614 to the (n-1)th LED array (not shown) to be constant currents, respectively, and thus can control the forward current (I_{f}) flowing through the LED array unit 610 (that is, first forward current (I_{f1}) + ... + (n-1)th forward current (I_{fn-1}) + nth forward current = forward current (I_{f}) to be a constant current.

In addition, as described above through FIG. 8, the constant current driver 620 may consist of one constant current driving circuit which controls the forward current to be a constant current by controlling subordinate forward currents of a plurality of LED arrays to be constant current, respectively.

FIG. 8 is an exemplary view illustrating the waveform of a PWM forward current of an LED which is controlled using the constant current driving circuit for driving a
PWM constant current in accordance with the first embodiment of the present invention.

As described above through FIGS. 4 and 5, in the LED driving circuit employing a common switching scheme, the waveform of the forward current (If) was not a perfect square waveform because of ripple occurring according to the switching. However, by using the constant current driving circuit for supplying an LED with a PWM constant current, the magnitude of the forward current (If) can be controlled in such a manner as to be a desired constant current, and at the same time can generate a forward current (If) of a perfect square waveform according to the external PWM control signal, as illustrated in FIG. 8.

Therefore, when the PWM type constant current driving circuit according to the preferred embodiment of the present invention is used, a hybrid scheme of the switching scheme and the linear control scheme can be utilized, so that a constant output voltage (Vo) is applied to the LED array unit 610 irrespective of a change in an input voltage (Vin) by using the switching converter 310, which results in no change in the forward current (If). At the same time, using the linear control scheme, a constant forward current (If) is applied to all LEDs by flowing a constant current having a clean square wave PWM waveform through the LED array unit 610, so that the uniformity of an optical output.
can be ensured. Furthermore, by adopting a scheme for adjusting the output of the switching converter 310 in such a manner as to reduce power consumption occurring in the constant current driving circuit of the linear control scheme, a high-efficiency PWM type constant current driving circuit can be implemented.

FIG. 9 is a circuit diagram illustrating an LED driving circuit for conducting a PWM control in accordance with a second preferred embodiment of the present invention. The LED driving circuit for conducting a PWM control according to the second preferred embodiment of the present invention is a PWM type LED driving circuit for supplying an LED with a constant current when a commercial AC power supply is used as an input power supply.

The LED driving circuit for conducting a PWM control according to the second embodiment of the present invention includes the output capacitor 320, the LED array unit 610, the constant current driver 620 and the feedback controller 630, which have been described above through FIG. 6. In addition to these constitutional elements, the LED driving circuit for conducting a PWM control according to the second embodiment of the present invention further includes an input AC power supply 910, a Power Factor Controller (hereinafter referred to as "PFC") 920, a smoothing capacitor (Cin) 930 and an isolation type switching
In the following description, a repetitive description of the constitutional elements, which have been already described above through FIG. 6, will be omitted.

The input AC power supply 910 is a commonly used commercial AC power supply, and supplies an input AC voltage (Vac) to the circuit. The PFC 920 reduces the harmonic distortion of an input AC current (Iac) supplied from the input AC power supply 910, improves a power factor, and supplies a DC power source by converting AC into DC.

The smoothing capacitor 930 reduces ripple contained in an output voltage of the PFC 920, and serves as an input DC voltage for the isolation type switching converter 940.

The isolation type switching converter 940 converts an DC voltage, transferred from the smoothing capacitor 930, into an output voltage (Vo) above the forward voltage (Vf). When the input power source is an AC power source, as illustrated in the drawing, the isolation type switching converter 940 enabling isolation between an input and an output must be used. The isolation type switching converter 940 may employ a power conversion scheme, including a common flyback converter, a common forward converter and so forth, according to its capacity and type.

In the LED driving circuit for conducting a PWM control according to the second embodiment of the present invention, if the input AC power source 910 is supplied to the circuit,
the PFC 920 conducts the operations of reducing a harmonic distortion, improving a power factor, and converting AC into DC, and then supplies the converted DC power source. Further, if the DC power source is supplied to the smoothing capacitor 930, the smoothing capacitor 930 transfers a constant DC voltage to the isolation type switching converter 940 while accumulating therein charges, and the isolation type switching converter 940 isolates primary and secondary switching circuits from each other, converts the input DC voltage into an output voltage \( (V_o) \) equal to or greater than the forward voltage \( (V_f) \), and transfers the converted output voltage \( (V_o) \) to the LED array unit 610. Subsequently, the constant current driver 620 and the feedback controller 630 control the forward current \( (I_f) \) to a constant current in the form of a PWM square wave, as described through FIGS. 6 to 8.

While this invention has been described in connection with what is presently considered to be the most practical and preferred embodiment, it is to be understood that the present invention is not limited to the disclosed embodiment and the drawings, but, on the contrary, it is intended to cover various modifications and variations within the spirit and scope of the appended claims.
As described above, the present invention controls a forward current flowing in an LED to be a PWM constant current of a perfect square waveform by using a constant current driving circuit in which a switching converter is combined with a linear control scheme. Also, using the switching converter, the present invention can prevent a change in the forward current of an LED array unit and thus a change in an optical output of the LED from being caused by the fluctuation of an input power source.

Further, the present invention can obtain a clean constant current waveform by using a constant current driving circuit which employs the linear control scheme and is connected in series to the LED array unit, and minimizes a voltage drop of the constant current driving circuit employing the linear control scheme by controlling an output voltage of the switching converter, thereby overcoming inefficiency in the linear control scheme and thus making it possible to implement a high-efficiency PWM constant current driving circuit.
Claims

1. An LED driving circuit for supplying a plurality of LEDs with a constant current, the LED driving circuit comprising:
   an input DC power supply for supplying a DC voltage;
   a switching converter, connected in series to the input DC power supply, for being supplied with the DC voltage from the input DC power supply, converting the DC voltage into an output voltage \( (V_o) \) in a switching scheme, the output voltage \( (V_o) \) corresponding to a voltage for driving the plurality of LEDs, and being equal to or greater than a prescribed voltage level, and delivering a converted output voltage \( (V_o) \);
   an LED array unit, connected in series to the switching converter, and including the plurality of LEDs connected in series or in series-parallel, each of which flows therethrough a forward current \( (I_f) \) therethrough to emit light if the output voltage \( (V_o) \) is delivered thereto from the switching converter;
   a constant current driver, connected in series to the LED array unit, for controlling the forward current \( (I_f) \) to be the constant current; and
   a feedback controller, connected to one or more of a first stage between the switching converter and the LED
array unit and a second stage between the LED array unit and the constant current driver, for controlling the switching converter in such a manner that the output voltage \( (V_o) \) is equal to or greater than at least an forward voltage \( (V_f) \) of the LED array unit.

2. The LED driving circuit as claimed in claim 1, wherein the constant current driver is connected in series between the LED array unit and a ground.

3. The LED driving circuit as claimed in claim 1, wherein, if the feedback controller is connected to all of the first and second stages, the feedback controller senses the output voltage \( (V_o) \) and a both-end voltage of the constant current driver, and controls the switching converter in such a manner that the output voltage \( (V_o) \) becomes a sum of the forward voltage \( (V_f) \) of the LED array unit and a voltage drop \( (V_d) \) of the constant current driver.

4. The LED driving circuit as claimed in claim 1, wherein, if the feedback controller is connected to only the first stage, the feedback controller senses the output voltage \( (V_o) \), and controls the switching converter in such a manner that the output voltage \( (V_o) \) becomes a sum of the forward voltage \( (V_f) \) of the LED array unit and a
5. The LED driving circuit as claimed in claim 1, wherein, if the feedback controller is connected to only the second stage, the feedback controller senses a voltage drop \((V_d)\) of the constant current converter, and controls the switching converter in such a manner that a value of the voltage drop \((V_d)\) of the constant current driver becomes a predetermined minimum value.

6. The LED driving circuit as claimed in claim 4, wherein the feedback controller further conducts a control for preventing abnormal operations or breakage from being caused by one or more of a temperature, an overvoltage and an excess current.

7. The LED driving circuit as claimed in claim 1, wherein the constant current driver comprises:

   a sensing resistor for sensing a forward current \((I_f)\) flowing through the LED array unit;

   an amplifier, connected to between a transistor and the sensing resistor, for sensing the forward current \((I_f)\), flowing in the LED array unit and the transistor, as a sensed voltage generated by the sensing resistor, and then
amplifying a difference between the sensed voltage and a reference voltage (Vref) to deliver an amplified voltage value;

- a constant current PWM on/off driving circuit for receiving the amplified voltage value from the amplifier and adjusting a base current of the transistor, thereby flowing the constant current in the LED array unit which is connected in series to the transistor; and

The transistor connected to the LED array unit and connected to the constant current PWM on/off driving circuit, for flowing the forward current in the LED array unit according to a control of the constant current PWM on/off driving circuit.

8. The LED driving circuit as claimed in claim 7, wherein, if the constant current PWM on/off driving circuit externally receives an on/off PWM waveform, the constant current PWM on/off driving circuit on/off controls a base of the transistor to thereby form a waveform of the constant current into a square wave PWM waveform.

9. The LED driving circuit as claimed in claim 1, wherein the LED array unit includes one or more LED arrays among a first LED array to an nth LED array, in each of which the plurality of LEDs are connected in series or in
series-parallel, and the constant current driver includes one or more constant current driving circuits among a first constant current driving circuit to an nth constant current driving circuit which correspond one-to-one to the one or more LED arrays.

10. The LED driving circuit as claimed in claim 9, wherein the one or more constant current driving circuits control a plurality of subordinate forward currents, each flowing through each of the one or more LED arrays corresponding one-to-one thereto, respectively, thereby controlling the forward current (If) to be the constant current.

11. The LED driving circuit as claimed in claim 1, wherein the LED array includes one or more LED arrays among a first LED array to an nth LED array, in each of which the plurality of LEDs are connected in series or in series-parallel, and the constant current driver is connected to the one or more LED arrays, and simultaneously controls a plurality of subordinate forward currents, each flowing through each of the one or more LED arrays, thereby controlling the forward current (If) to be the constant current.
12. A constant current driving circuit for driving a plural of LEDs, by supplying the plurality of LEDs with a constant current, comprising:

   a sensing resistor for sensing a forward current (If) flowing through the plurality of LEDs;

   an amplifier, connected between a transistor and the sensing resistor, for sensing the forward current (If), to thereby produce a sensed voltage across the sensing resistor, and amplifying a difference between the sensed voltage and a reference voltage (Vref) to generate an amplified voltage value;

   a constant current PWM on/off driving circuit for receiving the amplified voltage value and adjusting a base current of a transistor, thereby flowing the constant current in the plurality of LEDs; and

   the transistor, connected to the plurality of LEDs and to the constant current PWM on/off driving circuit, for flowing the forward current in the plurality of LEDs under the a control of the constant current PWM on/off driving circuit.

13. The constant current driving circuit as claimed in claim 12, wherein, if the constant current PWM on/off driving circuit externally receives an on/off PWM waveform, the constant current PWM on/off driving circuit on/off
controls a base of the transistor to thereby form a waveform of the constant current into a square wave PWM waveform.

14. An LED driving circuit for supplying a plurality of LEDs with a constant current, comprising:

an input AC power supply for supplying an AC voltage;

a PFC (Power Factor Controller), connected in series to the input AC power supply, for being supplied with the AC voltage from the input AC power supply, reducing a harmonic distortion of the AC voltage and converting the AC voltage into a DC voltage;

a smoothing capacitor for receiving the AC voltage from the PFC, accumulating therein charges, and producing a constant DC voltage;

an isolation type switching converter, connected in series to the PFC and connected in parallel to the smoothing capacitor, for receiving the constant DC voltage, converting the constant DC voltage into a voltage which is equal to or greater than a reference voltage (V_{ref}) to be applied to the plurality of LEDs, and delivering an output voltage (V_o);

an LED array unit connected in series to the isolation type switching converter, and including the plurality of LEDs connected in series or in series-parallel,
each of the LEDs flows a forward current (If) therethrough to emit light if the output voltage (Vo) is applied thereto;

a constant current driver, connected in series to the LED array unit, for controlling the forward current (If) to be the constant current; and

a feedback controller, connected to one or more of a first stage between the switching converter and the LED array unit and a second stage between the LED array unit and the constant current driver, for controlling the switching converter in such a manner that the output voltage (Vo) is equal to or greater than an forward voltage (Vf) of the LED array unit.
FIG. 1
FIG. 2
FIG. 5
FIG. 7
FIG. 8
A. **CLASSIFICATION OF SUBJECT MATTER**

**H03K 7/08(2006.01)i**

According to International Patent Classification (IPC) or to both national classification and IPC

B. **FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)

IPC 8  H03K 7/08

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Korean Patents and Applications for invention since 1975
Korean Utility and Applications for Utility since 1975

Electronic database consulted during the international search (name of database and, where practicable, search terms used)

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C. **DOCUMENTS CONSIDERED TO BE RELEVANT**

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* Special categories of cited documents
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Date of the actual completion of the international search  
30 JANUARY 2007 (30 01 2007)

Date of mailing of the international search report  
30 JANUARY 2007 (30.01.2007)

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