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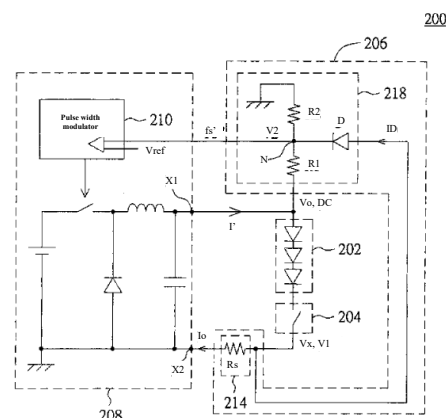
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3 pages of Claims, 7 pages of Specifications, 8 pages of
 Attached Drawings

[54] Title of Invention Driving Device for Light-emitting Diode Series

[57] Abstract

A driving device for a light-emitting diode series, comprising a direct current-direct current converter, the light-emitting diode series, a switch and a feedback circuit. The direct current-direct current converter has a first direct current-direct current converter end, and outputs a direct current voltage at the first direct current-direct current converter end according to a feedback signal. The light-emitting diode series is connected to the first direct current-direct current converter end. The switch is connected with the light-emitting diode series in series. When the switch is turned on, the light-emitting diode series is driven by the direct current voltage, and a direct-current current flows through the light-emitting diode series. The feedback circuit outputs the feedback signal according to the direct-current current. Wherein when the switch is turned on, the light-emitting diode series is quickly lit to a predetermined brightness; and when the switch is turned off, the light-emitting diode series is quickly extinguished.



1. A driving device for a light-emitting diode series, comprising:
 - a direct current-direct current converter which has a first direct current-direct current converter end and a second direct current-direct current converter end, wherein the second direct current-direct current converter end is connected to a fixed voltage, and the direct current-direct current converter outputs a direct current voltage at the first direct current-direct current converter end according to a feedback signal;
 - the light-emitting diode series connected to the first direct current-direct current converter end;
 - a switch which is connected with the light-emitting diode series in series, wherein when the switch is turned on, the light-emitting diode series is driven by the direct current voltage, and a direct-current current flows through the light-emitting diode series; and
 - a feedback circuit which outputs the feedback signal according to the direct-current current;
 - wherein when the switch is turned on, the light-emitting diode series is quickly lit to a predetermined brightness; and when the switch is turned off, the light-emitting diode series is quickly extinguished.
2. The device of Claim 1, wherein the light-emitting diode series comprises one light-emitting diode or a plurality of light-emitting diodes connected in series.
3. The device of Claim 1, wherein the feedback circuit comprises:
 - a current-voltage converter which has a first end and a second end, wherein the first end is connected to the switch, and the second end is connected to the second direct current-direct current converter end; and when the switch is turned on, the direct-current current flows into the current-voltage converter, so that the current-voltage converter generates a first reference voltage as the feedback signal according to the direct-current current.
4. The device of Claim 3, wherein the direct current-direct current converter comprises:
 - a pulse width modulator which adjusts an output signal of the pulse width modulator according to the feedback signal, so that the direct current-direct current converter outputs the stable direct current voltage.
5. The device of Claim 4, wherein the current-voltage converter is a resistor, one end of the resistor is the first end, and the other end of the resistor is the second end; and after the direct-current current flows through the resistor, the first reference voltage is generated at the first end, and fed back to the pulse width modulator.
6. The device of Claim 5, wherein the driving device for the light-emitting diode series further comprises:
 - an amplifier which is bridged to the first end of the current-voltage converter and the pulse width modulator, and used to amplify the feedback signal to output it to the pulse width modulator.
7. The device of Claim 1, wherein the direct current-direct current converter has a pulse width modulator, the pulse width modulator adjusts the output signal of the pulse width modulator according to the feedback signal, so that the direct current-direct current converter outputs the stable direct current voltage, the feedback circuit comprises:

a current-voltage converter which has a first end and a second end, wherein the first end is connected to the switch, and the second end is connected to the second direct current-direct current converter end; when the switch is turned on, the direct-current current flows into the current-voltage converter, so that the current-voltage converter generates a first reference voltage as the feedback signal according to the direct-current current;

a voltage feedback circuit which generates a second reference voltage according to the direct current voltage as the feedback signal when the switch is turned off, the voltage feedback circuit comprises:

a first impeder which has a first impeder first end and a first impeder second end, wherein the first impeder first end is connected to the direct current voltage, the first impeder second end is connected to a node, and the node is connected to the pulse width modulator;

a second impeder, wherein one end of the second impeder is connected to the node, the other end of the second impeder is connected to the fixed voltage, and a voltage of the node serves as the second reference voltage; and

a diode, wherein a negative end (N-terminal) of the diode is connected to the node, and a positive end (P-terminal) of the diode is connected to the first end of the current-voltage converter;

wherein when the switch is turned on, the first reference voltage determines the second reference voltage by turning on the diode, and the feedback circuit uses the second reference voltage as the feedback signal;

wherein when the switch is turned off, the diode is also turned off, at this time, the second reference voltage is determined by the direct current voltage through a partial voltage of the first impeder and the second impeder, and the feedback circuit uses the second reference voltage as the feedback signal.

8. The device of Claim 7, wherein the current-voltage converter is a resistor, one end of the resistor is the first end, and the other end of the resistor is the second end; and when the direct-current current flows through the resistor, the first reference voltage is generated at the first end, and is connected to the pulse width modulator via the diode.

9. The device of Claim 8, wherein the driving device for the light-emitting diode series further comprises:

an amplifier which is bridged to the first end of the current-voltage converter and the positive end of the diode, and used to amplify the feedback signal and output it to the pulse width modulator.

10. The device of Claim 1, wherein the fixed voltage is a ground voltage.

11. The device of Claim 1, wherein the direct current-direct current converter is a buck converter.

12. The device of Claim 1, wherein the direct current-direct current converter is a boost converter.

13. The device of Claim 1, wherein the direct current-direct current converter is a boost-buck converter.

14. The device of Claim 1, wherein the direct current-direct current converter is a full-bridge converter.

15. The device of Claim 1, wherein the direct current-direct current converter is a flyback converter.

16. The device of Claim 1, wherein the driving device for the light-emitting diode is used in a backlight module of a liquid crystal display.

Driving Device for Light-emitting Diode Series

Technical field

The present invention relates to a driving device for a light-emitting diode series, and in particular to a driving device for a light-emitting diode series for a backlight module.

Background art

Conventional liquid crystal displays (LCDs) use backlight modules to provide light required by LCD panels, and their light sources can be generated via light-emitting diodes (LEDs). Light-emitting diodes (LEDs) are a type of solid-state semiconductor light sources, and have multiple characteristics: ultra-long life, power saving, low operating voltage, low temperature operation and fast reaction speed, which are advantages that light sources of current cold cathode fluorescent lamps (CCFLs) cannot match, so that light sources produced by the light-emitting diodes (LEDs) have been widely used in multi-lighting and small-size mobile phone backlight modules. The light-emitting diodes (LEDs) have gradually replaced the cold cathode fluorescent lamps (CCFLs) as a clear trend in the future.

Please refer to Figure 1A, which represents a circuit diagram of a conventional driving device for a light-emitting diode series. The driving device 100 comprises a direct current voltage source 102, a DC chopper 104, a filtering circuit 106 and the light-emitting diode series 108. Electrical connection from the direct current voltage source 102 to the light-emitting diode series 108 is controlled via the DC chopper 104, so that the light-emitting diode series 108 can be turned on/off, i.e., lit or extinguished. Since the filtering circuit 106 has an inductor, a wave pattern of a current I of the light-emitting diode series 108 presents a triangular wave, please refer to Figure 1B, it is impossible for the light-emitting diode series 108 to operate at a fixed turn-on current. Even if the light-emitting diode series 108 is connected with a voltage regulating capacitor in parallel, the current I of the light-emitting diode series 108 is relatively stable, but there is a phenomenon of too slow capacitor charging and discharging, and the light-emitting diode series 108 cannot be quickly turned on or off.

Summary of the Invention

In view of this, an objective of the present invention is to provide a driving device for a light-emitting diode series, so as to operate at a fixed turn-on current and make the light-emitting diode series be quickly lit or extinguished.

According to the objective of the present invention, the driving device for the light-emitting diode series is provided, which comprises a direct current-direct current converter (DC-DC converter), a light-emitting diode series (LED string), a switch and a feedback circuit. The direct current-direct current converter has a first direct current-direct current converter end, and outputs a direct current voltage at the first direct current-direct current converter end according to a feedback signal. The light-emitting diode series is

connected to the first direct current-direct current converter end. The switch is connected with the light-emitting diode series in series. When the switch is turned on, the light-emitting diode series is driven by a direct current voltage, and a direct-current current flows through the light-emitting diode series. The feedback circuit outputs the feedback signal according to the direct-current current. Wherein when the switch is turned on, the light-emitting diode series is quickly lit to a predetermined brightness, and when the switch is turned off, the light-emitting diode series is quickly extinguished.

Brief Description of the Drawings

In order to make the above objectives, characteristics and advantages of the present invention more obvious and understandable, a preferred example is described below; and in conjunction with the drawings, the details are as follows:

Figure 1A represents a circuit diagram of a conventional driving device for a light-emitting diode series.

Figure 1B represents a waveform diagram of currents I and I_s of Figure 1A.

Figure 2 represents a circuit diagram of a driving device for a light-emitting diode series according to a first example of the present invention.

Figure 3 represents a circuit diagram of a driving device for a light-emitting diode series according to a second example of the present invention.

Figure 4 represents a circuit diagram of a driving device for a light-emitting diode series according to a third example of the present invention.

Figure 5 represents a circuit diagram of a driving device for a light-emitting diode series with a boost converter.

Figure 6 represents a circuit diagram of a driving device for a light-emitting diode series with a boost-buck converter.

Figure 7 represents a circuit diagram of a driving device for a light-emitting diode series with a flyback converter.

Figure 8 represents a circuit diagram of a driving device for a light-emitting diode series with a full-bridge converter.

Description of labels of drawings

100 : conventional driving device for light-emitting diode series

102 : direct current voltage source

104 : direct current chopper

106 : filtering circuit

200 : driving device for light-emitting diode series

108, 202: light-emitting diode series

204 : switch

206 : feedback circuit

208 : direct current-direct current converter

210 : pulse width modulator

214 : current-voltage converter

216 : amplifier
218 : voltage feedback circuit
D : diode
Rs : resistor
R1, R2: impeder

Detailed Description of Embodiments

Embodiment 1

Please refer to Figure 2, which represents a circuit diagram of a driving device for a light-emitting diode series according to a first example of the present invention. The driving device 200 may be used in a backlight module of a liquid crystal display, and comprises a direct current-direct current converter 208 (DC-DC converter), the light-emitting diode series 202 (LED string), a switch 204 and a feedback circuit 206. Wherein in the present example, a description is made with the direct current-direct current converter 208 being the buck converter as an example. However, the light-emitting diode series 202 is used to provide a light source required by a liquid crystal panel.

The direct current-direct current converter 208 has a first direct current-direct current converter end X1 and a second direct current-direct current converter end X2. The second direct current-direct current converter end X2 is connected to a fixed voltage, and the fixed voltage is, for example a ground voltage. The direct current-direct current converter 208 outputs a direct current voltage DC at the first direct current-direct current converter end X1 according to a feedback signal fs. The light-emitting diode series 202 is connected to the first direct current-direct current converter end X1. The switch 204 is connected with the light-emitting diode series 202 in series. When the switch 204 is turned on, the light-emitting diode series 202 is driven by the direct current voltage DC, and a direct-current current P flows through the light-emitting diode series 202 to emit a light source. The feedback circuit 206 outputs the feedback signal fs according to a direct-current current I'.

In order to enable the light-emitting diode series 202 to be quickly turned on or off, that is lit or extinguished, the present example achieves the above objective by making the switch 204 connected with the light-emitting diode series 202 in series. When the switch 204 is turned on, a fixed turn-on current flows through the light-emitting diode series 202, and the light-emitting diode series is rapidly lit to a predetermined brightness; and when the switch 204 is turned off, the current flowing through the light-emitting diode series 202 stops immediately, and the light-emitting diode series 202 is quickly extinguished. This can avoid slow direct-current current I' changes caused by energy storage assemblies in the direct current-direct current converter 208, and the speed at which the light-emitting diode series 202 is lit or extinguished is reduced. Even more, because the light-emitting diode series 202 is controlled via this switch 204 to be quickly turned on or off, values of energy storage assemblies (such as capacitors and inductors) of the direct current-direct

current converter 208 can be increased, thereby making the output direct-current current I' more stable.

The direct current-direct current converter 208 comprises a pulse width modulator 210. The feedback circuit 206 outputs the feedback signal f_s according to the direct-current current I' , causing the pulse width modulator 210 to adjust an output signal of the pulse width modulator 210 according to the feedback signal f_s , so that the direct current-direct current converter 208 outputs a stable direct current voltage DC. Still further, the feedback circuit 206 comprises a current-voltage converter 214. The current-voltage converter 214 has a first end and a second end. The first end is connected to the switch 204, and the second end is connected to the second direct current-direct current converter end X2 of the direct current-direct current converter 208. The current-voltage converter 214 is, for example, a resistor R_s . When the switch 204 is turned on, the direct-current current I' flows into the current-voltage converter 214, causing the current-voltage converter 214 to generate a first reference voltage V_I as the feedback signal f_s according to the direct-current current I' . Therefore, the direct current-direct current converter 208 controls the magnitude of the direct-current current I' according to the feedback signal f_s , so as to achieve a constant color temperature of the backlight module.

Moreover, in another example derived from the present example, when a plurality of light-emitting diode series are each driven by respective direct current-direct current converters, and magnitudes of respective direct-current currents I' can be controlled via respective feedback circuits, so that light-emitting diodes with different characteristics can all have the same current to flow through on the different light-emitting diode series 202, so as to produce the same brightness without differences in brightness, which can make the brightness of the backlight module consisting of the plurality of light-emitting diode series more uniform.

Embodiment 2

Please refer to Figure 3, which represents a circuit diagram of a driving device for a light-emitting diode series according to a second example of the present invention. The difference between the first example and the present example is that the driving device 200 also comprises an amplifier 216, which is bridged between the first end of the current-voltage converter 214 and the pulse width modulator 210. Moreover, the resistor R_s' of the present example may use a resistance value that is smaller than a value of the resistor R_s of the first example, which may reduce the power loss of the resistor R_s' . After the smaller first reference voltage V_I' is amplified via the amplifier 216, a feedback signal f_s' is generated to be output to the pulse width modulator 210. Thus, the present example can still produce a feedback signal f_s' with a voltage magnitude close to that of the feedback signal f_s of the first example, so that the direct current-direct current converter 208 can control the magnitude of the direct-current current I' according to the feedback signal f_s' as well, the brightness of the light-emitting diode series can be maintained fixed, and the constant color temperature of the backlight module can be realized. Furthermore, in another example derived from this example, when a plurality of light-emitting diode

series are driven by respective direct current-direct current converters, and magnitudes of respective direct-current currents I' can be controlled via respective feedback circuits, so that light-emitting diodes with different characteristics can all produce the same brightness on the different light-emitting diode series 202 without differences in brightness, and the brightness of the backlight module is more averaged.

Embodiment 3

Please refer to Figure 4, which represents a circuit diagram of a driving device for a light-emitting diode series according to a third example of the present invention. In the first example and the second example, when the switch 204 is turned off, since the direct-current current I' cannot be generated, the feedback circuit 206 cannot output a feedback signal f_s'' according to a first reference voltage V_1'' , at this time, the direct current-direct current converter 208 cannot know a voltage value of a current direct current voltage DC for control, causing the current direct voltage DC to shift; and when the light-emitting diode series 202 is lit again, a predetermined brightness cannot be quickly achieved.

Therefore, difference between the present example and the first example and the second example is that the feedback circuit 206 also comprises a voltage feedback circuit 218. When the switch 204 is turned off, the voltage feedback circuit 218 generates a second reference voltage V_2 as the feedback signal f_s'' according to the direct current voltage DC.

Furthermore, the voltage feedback circuit 218 comprises a first impeder R1, a second impeder R2 and a diode D. The first impeder R1 has a first impeder first end and a first impeder second end, the first impeder first end is connected to the direct current voltage DC, and the first impeder second end is connected to a node N. The node N is connected to the pulse width modulator 210. One end of the second impeder R2 is connected to the node N, and the other end of the second impeder R2 is connected to the fixed voltage. A negative end (N-terminal) of the diode D is connected to the node N, while a positive end (P-terminal) of the diode is connected to the first end of the current-voltage converter 214. A voltage of the node N serves as the second reference voltage V_2 . That is, when the switch 204 is turned off, the diode D is also turned off, at this time, the second reference voltage V_2 is determined by the direct current voltage DC through a partial voltage of the first impeder R1 and the second impeder R2. At this time, the feedback circuit 206 uses the second reference voltage V_2 as the feedback signal f_s'' to feedback to the pulse width modulator 210. Thus, when the switch 204 is turned off and the light-emitting diode series 202 is extinguished, the direct current-direct current converter 208 maintains the magnitude of the direct current voltage DC according to the second reference voltage V_2 fed back, so that when the switch 204 is then turned on, there is no shift in the voltage value of the direct current voltage DC due to the excessively long turn-off time. Thus, when the light-emitting diode series 202 is lit again, a current close to the direct-current current I' in magnitude will rapidly flow through the light-emitting diode series 202, allowing the light-emitting diode series 202 to quickly achieve the predetermined brightness.

Likewise, when the switch 204 is turned on, a majority of the direct-current current I' flows into the current-voltage converter 214, causing the current-voltage converter 214 to generate a first reference voltage $V1'$ according to the direct-current current I' . However, the difference is that the first reference voltage $V1''$ determines the second reference voltage $V2o$ by turning on the diode D, at this time, the feedback circuit 206 uses the second reference voltage $V2$ as the feedback signal fs'' , with the prerequisite that the first reference voltage $V1''$ must turn on the diode D, that is, when the switch 204 is turned on, the first reference voltage $V1''$ must be greater than the voltage of the node N to determine the second reference voltage $V2$.

The following will further illustrate how to make the first reference voltage $V1''$ to determine the second reference voltage $V2$ by turning on the diode D. Assuming that when the switch 204 is turned off, the diode D is also turned off, at this time, when the direct current voltage $DC = Vo(off) = Vref (1+R1/R2)$ (Equation 1), $Vref$ is a reference signal, and a comparator in the pulse width modulator 210 receives this reference signal and compares it with the feedback signal fs'' . The first reference voltage $V1'' = Vx (off) = 0$. Assuming that when the switch 204 is turned on, the direct current voltage $DC = Vo (on)$, and the first reference voltage $V1'' = Vx (on)$. The first reference voltage $V1''$ determines the second reference voltage $V2$ by turning on the diode D, and for this purpose, the diode D must be turned on. From the feedback circuit, since the voltage of the node N is adjusted to be equal to $Vref$, the first reference voltage $V1''$ is $(Vref + VD_drop)$, wherein VD_drop is a forward bias when the diode D is turned on. the current flowing through the resistor is $Io = (Vref + VD_drop)/Rs$.

At this time, it can be seen from the KCL law that the current flowing into the node N is equal to the current flowing out of the node N (the voltage of the node N is $Vref$, and the current flowing through the diode D is ID). Therefore, we can obtain:

$$Vref/R2 = ID + (Vo (on) - Vref) / R1;$$

$$Vref (1 + R1/R2) = R1 * ID + Vo (on);$$

$$\text{As can be seen from (Equation 1), } Vo(off) = Vref(1 + R1/R2)$$

$$\text{therefore, we can obtain } Vo (off) = R1 * ID + Vo (on) \text{ (Equation 2).}$$

When the switch 204 is turned on, in order to turn on the diode D, the current ID needs to be greater than zero. Therefore, $Vo(on)$ must be less than $Vo(off)$, so that the first reference voltage $V1''$ can be fed back to the pulse width modulator 210. However, when actually designing an entire system, a value of $Vo(on)$ is first determined, and then a value of $Vo(off)$ that is slightly larger than that of $Vo(on)$ is found. The finding method of the value of $Vo(on)$ is usually that how many light-emitting diodes are in the light-emitting diode series 202 is first determined, and then the corresponding direct current voltage DC (i.e., $Vo(on)$) when the light-emitting diode series 202 is turned on is then determined. The value of $Vo (off)$ can be obtained via (Equation 1), i.e., by adjusting a ratio of the second impeder $R2$ to the first impeder $R1$, and the value of $Vref$.

Here's an example. Assuming that the direct-current current I' output to the light-emitting diode series 202 is 300 mA, at this time, the direct current voltage DC (i.e., $Vo(on)$) is 79 V, so the direct current voltage DC (i.e., $Vo(off)$) is set to be 80 V when the switch 204 is turned off. Assuming that $Vref$ is 2.5 V, and the first impeder $R1$ and the

second impedor R2 are resistors, therefore, the ratio of R1 to R2 can be determined from (Equation 1), and it is selected that $R2 = 6.45\text{ K}$ and $R1 = 200\text{ K}$. Therefore, in the case of forward bias of the diode D, the first reference voltage $V1''$ is 3.2 V ($V_{\text{ref}} + V_{\text{D_drop}} = 2.5\text{ V} + 0.7\text{ V}$), and the direct-current current $I' = 3.2\text{ V}/R_s + I_D = 300\text{ mA}$. In this case, the current flowing through R2 is $2.5\text{ V}/6.45\text{ K} = I_D + (V_{\text{O(on)}} - 2.5) / 200\text{ K}$, so $I_D = 0.005\text{ mA}$ is obtained via $200\text{ K} * I_D + 79 = 80$, it is substituted into the equation that the direct-current current I' is $300\text{ mA} = 3.2\text{ V}/R_s + 0.005$, and R_s is 10.67 Ohms . Therefore, in order to maintain the forward bias of the diode D, the ratio of the first impedor R1 to the second impedor R2 and the magnitude of the resistor R_s must be designed, so that the voltage $V_{\text{O(off)}}$ of the direct current voltage DC at the time when the switch 204 is turned off is greater than $V_{\text{O(on)}} = 79\text{ V}$. At this time, the current I_D is much smaller than the current I_{O} flowing through R_s , so the magnitude of the first reference voltage $V1''$ is still controlled by the resistor R_s .

The feedback circuit 206 described above may also be according to the finding method in the second example, and can be bridged between the first end of the current-voltage converter 214 and the positive end of the diode D via the amplifier 216, so that the value of the resistor R_s may select a smaller resistance value to reduce the power loss of the resistor R_s .

In addition, the direct current-direct current converter 208 in these three examples may also be replaced by other buck converter, boost converter, boost-buck converter, flyback converter or full-bridge converter, similarly allowing the light-emitting diode series 202 to be quickly extinguished and lit. The circuit diagrams of the driving device for the light-emitting diode series using the boost converter, the boost-buck converter, the flyback converter, and the full-bridge converter are shown in Figures 5-8, respectively.

The driving device for the light-emitting diode series disclosed in the above examples of the present invention can achieve the objective of rapidly lighting or extinguishing the light-emitting diode series, and has the advantage that after the light-emitting diode series is lit, the direct-current current flowing through the light-emitting diode series can be maintained stable, so that the brightness of the light-emitting diode series is maintained constant, and there is no difference due to the characteristics of the light-emitting diode series.

In summary, although the present invention has been disclosed as above with a preferred example, it is not intended to define the present invention, and those skilled in the art can make various changes and modifications without departing from the spirit and scope of the present invention, so the scope of protection of the present invention shall be subject to the scope defined by the proposed Claims.

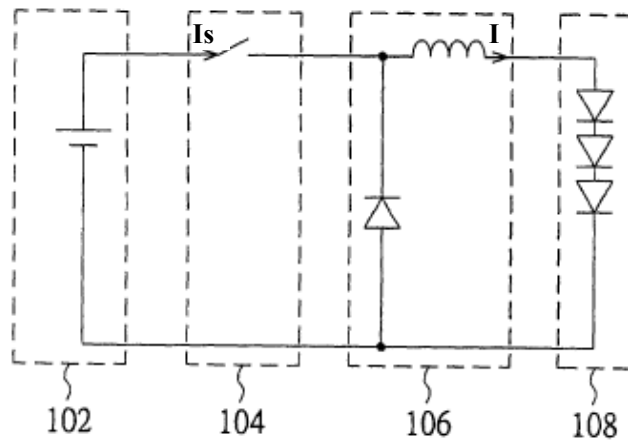


Figure 1A

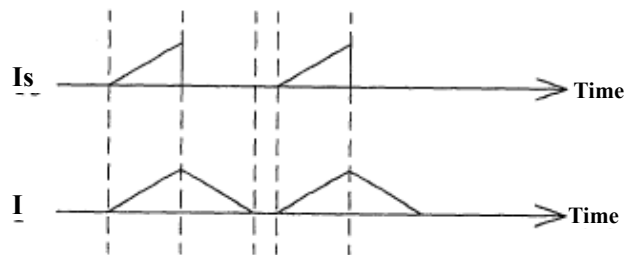
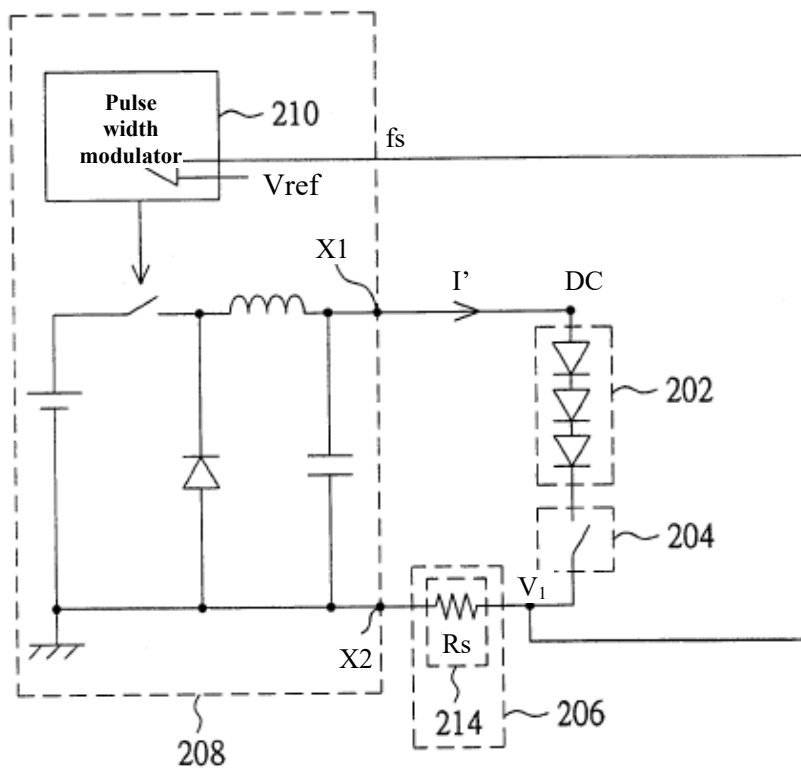


Figure 1B

**Figure 2**

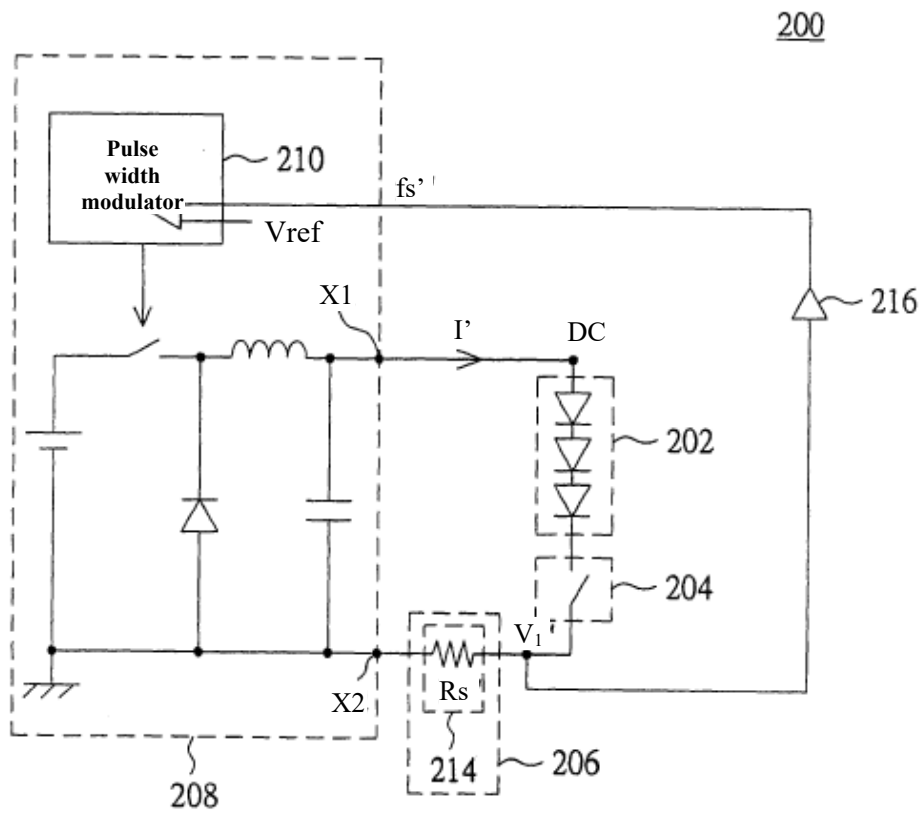


Figure 3

200

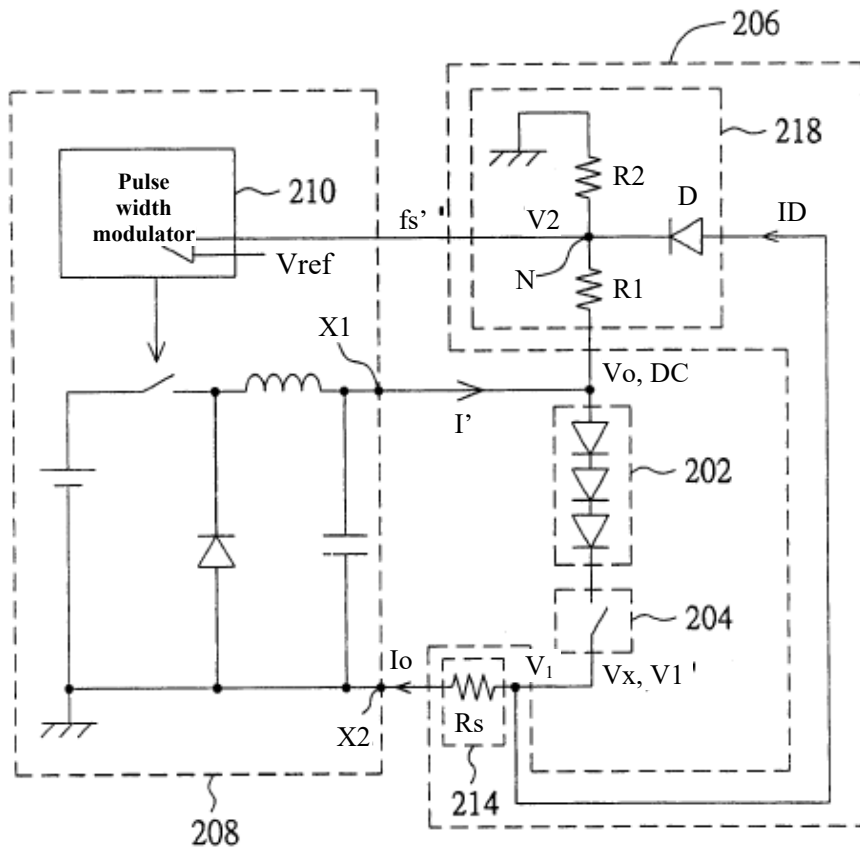


Figure 4

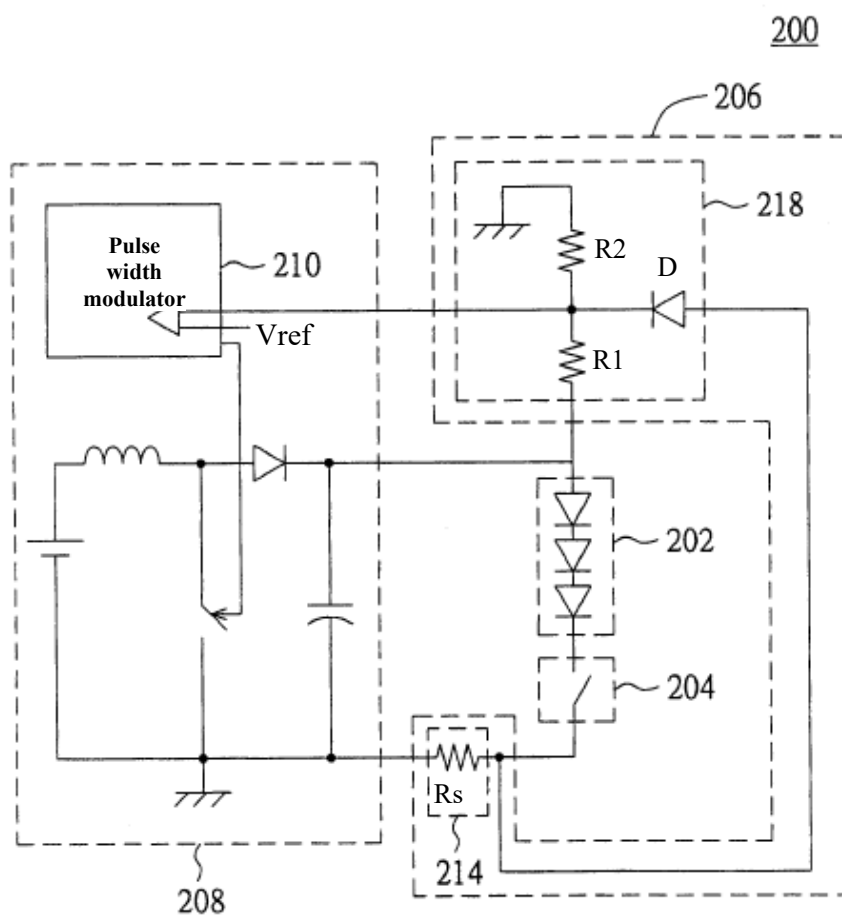


Figure 5

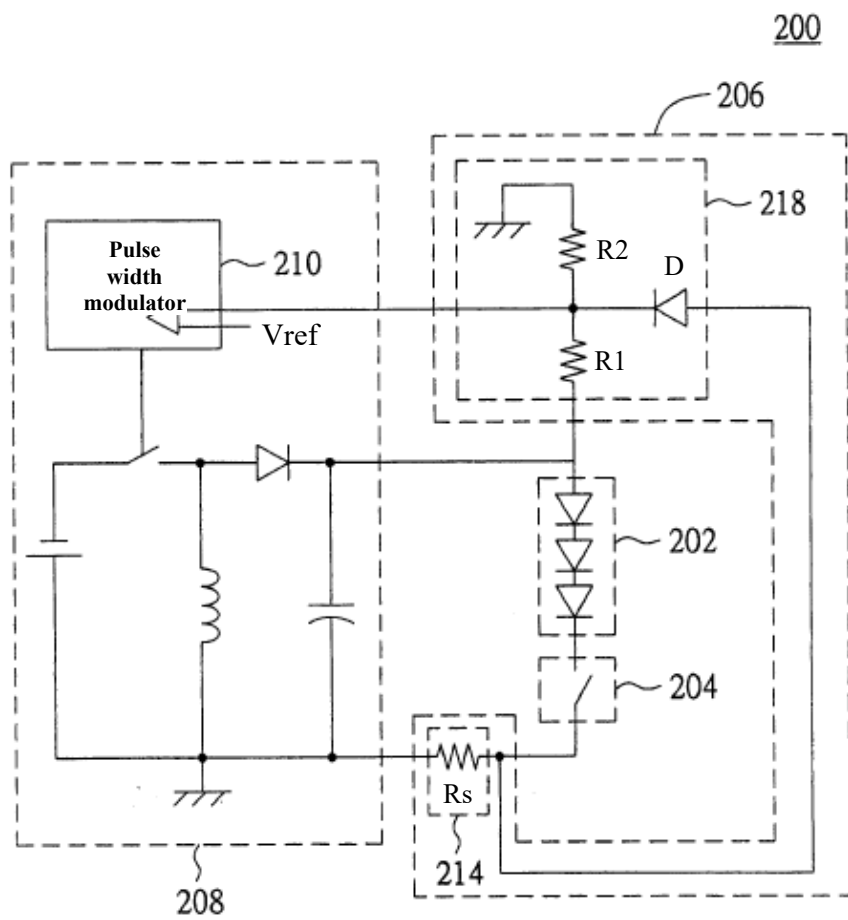


Figure 6

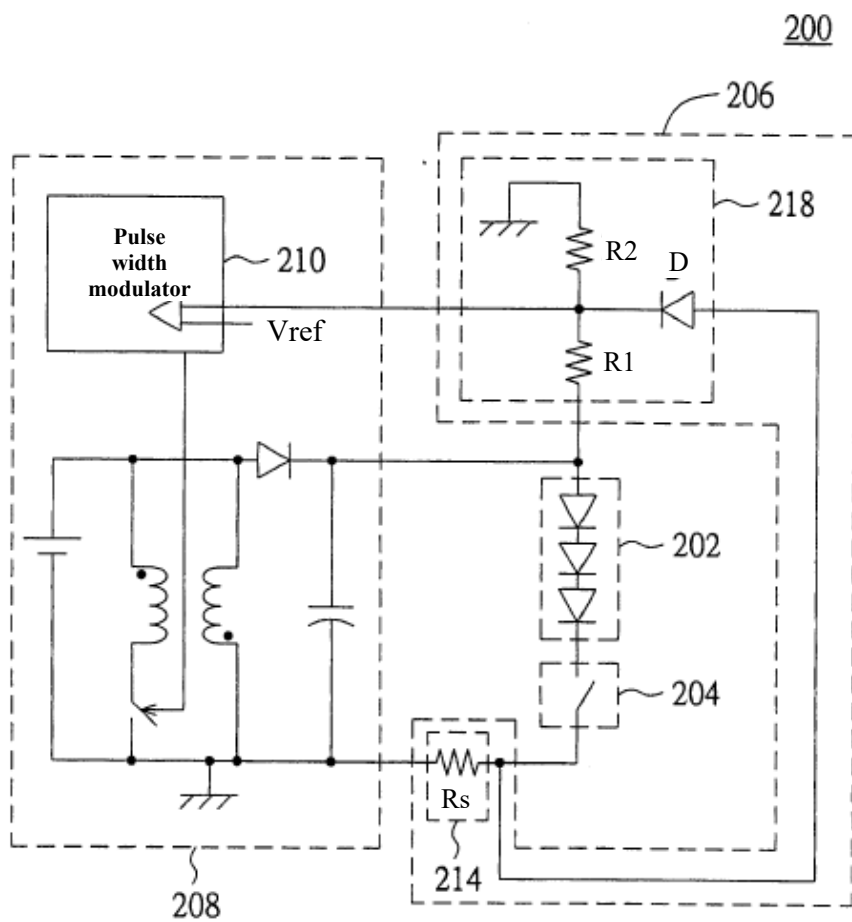


Figure 7

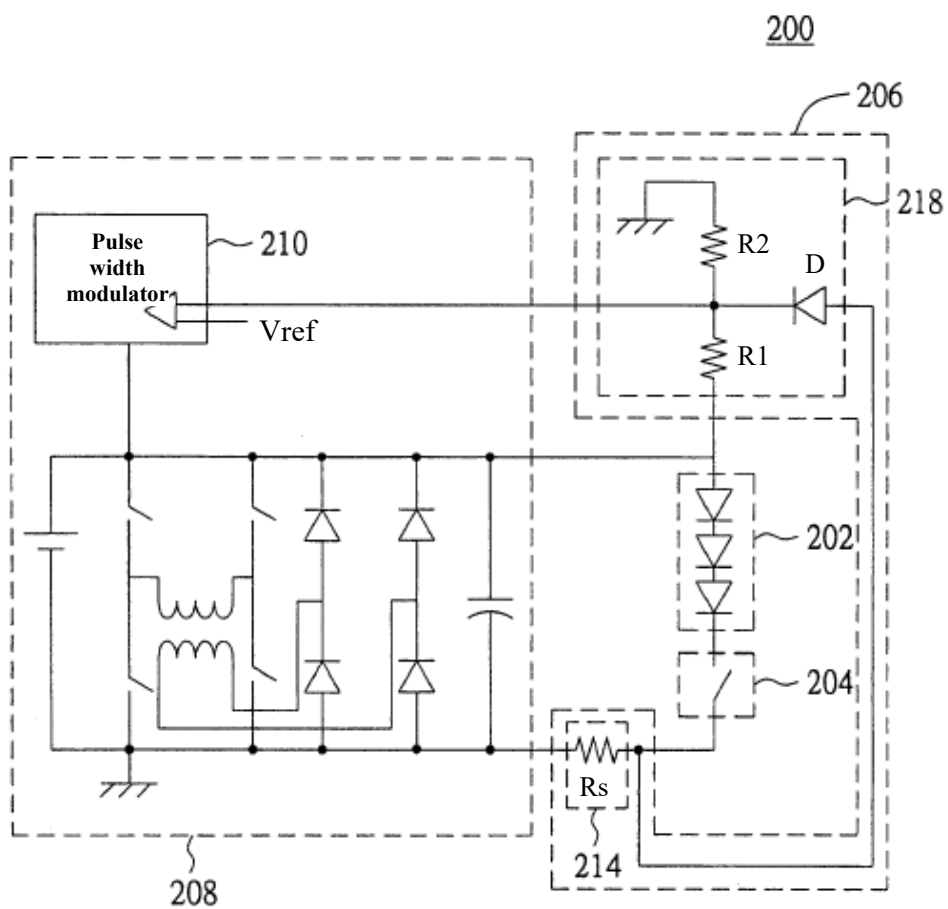


Figure 8



City of New York, State of New York, County of New York

I, Dan McCourt, hereby certify that the document “**CN1588523A**” is, to the best of my knowledge and belief, a true and accurate translation from Chinese into English.

A handwritten signature in black ink that reads 'Dan M'.

Dan McCourt

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A handwritten signature in black ink, likely belonging to Wendy Poon.

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