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(54) CURRENT CONTROL APPARATUS WITH HIGH PRECISION CONTROL

(57) A current control apparatus with high precision control is configured to provide a current control for an LED light string (LED_1). The current control apparatus includes a light string switch (Ql), a plurality of resistor branches (Br_1-Br_n), and a controller (100). The light string switch (Ql) is coupled in series to the LED light string (LED_1). The resistor branches (Br_1-Br_n) are electrically coupled to the LED light string (LED_1). Each of the resistor branches (Br_1-Br_n) includes a resistor (Rset_1-Rset_n) and a branch switch (Qr1-Qrn) coupled in series to the resistor (Rset_1-Rset_n). The controller (100) provides a light string control signal (LED_1_EN) and a plurality of branch control signals (LED _CTRL 1-LED CTRL_n). The light string control signal (LED_1_EN) turns on and turns off the LED light string (LED_1), and the branch control signals (LED_CTRL_1-LED_CTRL_n) respectively turn on and turn off the branch switches (Qrl-Qrn).

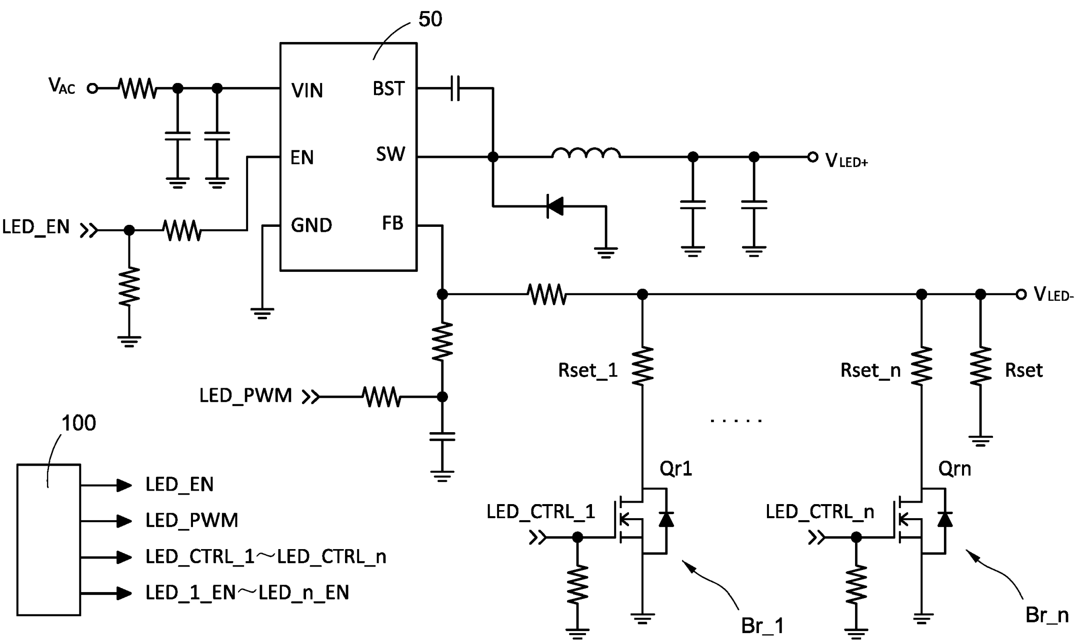

FIG.3

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Description

BACKGROUND

Technical Field

[0001] The present disclosure relates to a current control apparatus, and more particularly to a current control apparatus with high precision control for at least one LED light string.

Description of Related Art

[0002] The statements in this section merely provide background information related to the present disclosure and do not necessarily constitute prior art.

[0003] The electric mirror (or called smart mirror) is a digital electric mirror, which mainly captures the image of the human body through the camera lens, and then presents it on a screen thereof in a mirroring manner so that the users can look at their faces from the screen. However, in order to facilitate the environment to have enough brightness for the camera lens to capture images, a light source (such as, a fill light source) can also be set around the camera lens. By the principle of light source reflection, when the user activates the photographing mode of the electric mirror, the light source illuminates the face of the user, which can achieve the fill light illumination effect of the face, so that it is convenient for the camera lens to capture the face image. In addition, when the user activates the makeup mode of the electric mirror, the light provided by the light source (such as, a makeup light source) provided from the mirror surface can let the user know the condition of the makeup under the color temperature of the light source, thereby helping the user to easily complete the makeup work.

[0004] However, in the related art, multiple light source drivers are required for separately controlling the fill light source and the makeup light source. Take a single fill light source as an example, for the control of different color temperatures (for example, mixing light at 6500K and 2700K), at least two light source drivers are required. Similarly, for a single makeup light source, two light source drivers are also required. Therefore, it not only increases equipment costs and occupied area of the drivers, but also increases difficulty of circuit control.

SUMMARY

[0005] An object of the present disclosure is to provide a current control apparatus with high precision control to solve problems of increasing equipment costs and occupied areas of the drivers, and also increasing difficulty of circuit control.

[0006] In order to achieve the above-mentioned object, the current control apparatus with high precision control is configured to provide a current control for an LED light string. The current control apparatus includes a light string switch, a plurality of resistor branches, and a controller. The light string switch is coupled in series to the LED light string. The resistor branches are electrically coupled to the LED light string. Each of the resistor branches includes a resistor and a branch switch coupled in series to the resistor. The controller provides a light string control signal and a plurality of branch control signals. The light string control signal turns on and turns off the LED light string, and the branch control signals respectively turn on and turn off the branch switches.

[0007] In one embodiment, the branch switches are turned on and turned off to make the corresponding resistors electrically coupled in parallel so as to provide an equivalent resistance and determine a maximum current.

[0008] In one embodiment, when the branch switches are all turned on, the equivalent resistance is minimal; when the branch switches are all turned off, the equivalent resistance is maximal.

[0009] In one embodiment, the controller controls a duty cycle of a PWM signal to finely adjust the maximum current.

[0010] In one embodiment, the maximum current is finely adjusted by 1% intervals.

[0011] Accordingly, the current control apparatus with high precision control is provided to realize: 1. the luminous brightness of the individual LED light string can be controlled, or the luminous brightness of the multiple LED light strings can be simultaneously controlled so as to increase the diversity and flexibility of light source control applications, 2. by using fewer light source drivers, it is possible to reduce equipment costs, reduce occupied area of the driver, and reduce difficulty of circuit control. At the condition, different operation modes can be used to provide different maximum current supply range according to different usage scenarios and different brightness requirements, and 3. by controlling the duty cycle of the PWM signal, it can finely adjust the current flowing through the LED light string, such as by 1% intervals so that the high precision control of the current flowing through the LED light string can be implemented.

[0012] Another object of the present disclosure is to provide a current control apparatus with high precision control to solve problems of increasing equipment costs and occupied areas of the drivers, and also increasing difficulty of circuit control.

[0013] In order to achieve the above-mentioned object, the current control apparatus with high precision control is configured to provide a current control for an LED light string. The current control apparatus includes a plurality of light string switches, a plurality of resistor branches, and a controller. The light string switches are respectively coupled in series to the LED light strings. The resistor branches are electrically coupled to the LED light strings. Each of the resistor branches includes a resistor and a branch switch coupled in series to the resistor. The controller provides a plurality of light string control signals and a plurality of branch control signals. The light string control signals respectively turn on and turn off the LED light strings, and the branch control signals respectively turn on and turn off the branch switches.

[0014] In one embodiment, the branch switches are turned on and turned off to make the corresponding resistors electrically coupled in parallel so as to provide an equivalent resistance and determine a maximum current.

[0015] In one embodiment, when the branch switches are all turned on, the equivalent resistance is minimal; when the branch switches are all turned off, the equivalent resistance is maximal.

[0016] In one embodiment, the controller is configured to control a duty cycle of a PWM signal to finely adjust the maximum current.

[0017] In one embodiment, the maximum current is finely adjusted by 1% intervals.

[0018] In one embodiment, the current control apparatus is applied to an electric mirror, and one of the LED light string is used as a fill light source and the other of the LED light string is used as a makeup light source.

[0019] In one embodiment, a maximum current provided to the fill light source is larger than a maximum current provided to the makeup light source.

[0020] Accordingly, the current control apparatus with high precision control is provided to realize: 1. the luminous brightness of the individual LED light string can be controlled, or the luminous brightness of the multiple LED light strings can be simultaneously controlled so as to increase the diversity and flexibility of light source control applications, 2. by using fewer light source drivers, it is possible to reduce equipment costs, reduce occupied area of the driver, and reduce difficulty of circuit control. At the condition, different operation modes can be used to provide different maximum current supply range according to different usage scenarios and different brightness requirements, and 3. by controlling the duty cycle of the PWM signal, it can finely adjust the current flowing through the LED light string, such as by 1% intervals so that the high precision control of the current flowing through the LED light string can be implemented.

[0021] It is to be understood that both the foregoing general description and the following detailed description are exemplary, and are intended to provide further explanation of the present disclosure as claimed. Other advantages and features of the present disclosure will be apparent from the following description, drawings and claims.

BRIEF DESCRIPTION OF DRAWINGS

[0022] The present disclosure can be more fully understood by reading the following detailed description of the embodiment, with reference made to the accompanying drawing as follows:

FIG. 1 is a schematic diagram of an electric mirror having a fill light source and a makeup light source according to the present disclosure.

FIG. 2 is a block circuit diagram of a conventional LED driver circuit.

FIG. 3 is a circuit diagram of a plurality of resistor branches of the current control apparatus with high precision control according to the present disclosure.

FIG. 4 is a circuit diagram of a plurality of LED light strings of the current control apparatus with high precision control according to the present disclosure.

DETAILED DESCRIPTION

[0023] Reference will now be made to the drawing figures to describe the present disclosure in detail. It will be understood that the drawing figures and exemplified embodiments of present disclosure are not limited to the details thereof.

[0024] Please refer to FIG. 1, which shows a schematic diagram of an electric mirror having a fill light source and a makeup light source according to the present disclosure. The electric mirror 1 has a screen 2, and a photographic lens 3 is provided on the top of the electric mirror 1 (but not limited thereto). Furthermore, a fill light source 10 is arranged around the photographic lens 3, and the fill light source 10 is an LED light string having a plurality of LEDs. Therefore, according to the brightness and color temperature of the ambient light detected by a photo sensor (not shown) of the photographic lens 3, the fill light source 10 can provide the required brightness and color temperature according to detection results, and then the photographic lens 3 works in the photographing mode.

[0025] The screen 2 is a screen that has both a mirror function and a light transmission. When the screen 2 displays, the images acquired (and processed) through the photographic lens 3 can be displayed. When the screen 2 does not display, the screen 2 is regarded as a general optical mirror with a reflection function. Furthermore, a makeup light source 20 is arranged on both sides (but not limited here) inside the screen 2. The makeup light source 20 is an LED light string having a plurality of LEDs. Take the makeup light source 20 shown in FIG. 1 as an example, the makeup light source 20 has two LED light strings which are electrically coupled in parallel to each other. Under the makeup mode, the screen 2 is used as a mirror. The light provided by the makeup light source 20 can let the user know the condition of the makeup under the color temperature of the makeup light source 20, thereby helping the user to easily complete the makeup work. Specifically, the screen 2 is a half-penetrating mirror, and a back layer thereof is a liquid crystal display (LCD) screen. When the screen is turned off, it is like a general mirror. At this condition, the makeup light source 20 can be activated to illuminate the user's face. When the screen is turned on, the user can choose to take pictures and the pictures can be shown on the screen, and further the fill light source 10 will activate the fill light.

[0026] Please refer to FIG. 2, which shows a block circuit diagram of a conventional LED driver circuit. Traditionally, a set of LED drivers 50 can only drive a fixed current. A relationship of a current flowing through the LED light string (I_{LED}) is:

$$I_{LED}=\frac{V_{FB}}{R_{set}}$$

wherein, V_{FB} represents a feedback voltage, Rset represents a designed resistance. For example, it is assumed that the feedback voltage V_{FB} is 0.155 volts (its magnitude is related to an IC design value), and if the designed resistance Rset is 0.18 ohms, the current flowing through the LED light string (I_{LED}) is 861 mA. Furthermore, a controller 100 is used to control (adjust) a duty cycle of a PWM signal to finely divide the current flowing through the LED light string (I_{LED}) into 100 parts, i.e., duty cycle=1%, duty cycle=2%, ... and duty cycle=100%, and therefore each part of the divided current is 8.61 mA. Accordingly, the luminous brightness of the LED light string can be controlled by controlling the current flowing through the LED light string (I_{LED}). In one embodiment, the controller 100, i.e., a main controller IC, may be a digital controller, which has functions of digital signal processing, calculation, and control, for example but not limited to a microcontroller (MCU), a digital signal processor (DSP), a field-programmable gate array (FPGA), or an application-specific integrated circuit (ASIC).

[0027] As shown in FIG. 2, the controller 100 generates a driver enabled signal LED EN to the LED driver 50 to enable the LED driver 50 to drive the LED light string. Furthermore, the controller 100 generates a PWM signal LED_PWM to the LED light string to control a duty cycle of the PWM signal LED PWM so as to finely divide the current flowing through the LED light string (I_{LED}) into multiple parts, such as the above-mentioned 100 parts, thereby finely adjusting the luminous brightness of the LED light string. For the traditional LED driver circuit shown in FIG. 2, once the designed resistance Rset is fixed, the maximum adjustable current flowing through the LED light string (I_{LED}) is fixed, that is, the maximum luminous brightness of the LED light string is also fixed.

[0028] Please refer to FIG. 3 and FIG. 4, which show a circuit diagram of a plurality of resistor branches and a circuit diagram of a plurality of LED light strings of the current control apparatus with high precision control according to the present disclosure, respectively. The current control apparatus with high precision control is configured to provide a current control for an LED light string. In this embodiment, take one LED light string (for example the first LED light string) shown in FIG. 4 as an example. The current control apparatus includes a light string switch Q1, a plurality of resistor branches Br_1-Br_n, and a controller 100.

[0029] The light string switch Q1 is coupled in series to the LED light string LED_1 (as shown in FIG. 4), and a series-connected structure formed by the light string switch Q1 and the LED light string LED_1 is electrically coupled between an output end of a positive drive voltage V_{LED+} and an output end of a negative drive voltage V_{LED-}. The resistor branches Br_1-Br_n are electrically coupled to the LED light string LED_1 (as shown in FIG. 3), that is, the resistor branches Br_1-Br_n are electrically coupled to the output end of the negative drive voltage V_{LED-}. Each of the resistor branches Br_1-Br_n includes a resistor Rset_1-Rset_n and a branch switch Qrl-Qrn coupled in series to the resistor Rset_1-Rset_n.

[0030] As shown in FIG. 3, the controller 100 provides a light string control signal LED_1_EN and a plurality of branch control signals LED_CTRL_1-LED_CTRL_n. The light string control signal LED_1_EN is used to turn on and turn off the LED light string LED_1. The branch control signals LED_CTRL_1-LED_CTRL_n are used to respectively turn on and turn off the branch switches Qrl-Qrn. For example, the branch control signal LED_CTRL_1 is used to turn on and turn off the branch switch Qr1, the branch control signal LED_CTRL_2 is used to turn on and turn off the branch switch Qr2, and so on.

[0031] For example, if a current flowing through the LED light string LED_1 is controlled, the controller 100 provides the light string control signal LED_1_EN turns on the light string switch Q1 so that the LED light string LED_1 is driven by the positive drive voltage V_{LED+} and the negative drive voltage V_{LED-}. For the resistor branches Br_1-Br_n, if the branch switches Qr1-Qrn are all turned on by the corresponding branch control signals LED_CTRL_1-LED_CTRL_n, the resistors Rset_1-Rset_n and a designed resistor Rset are connected in parallel so that an equivalent resistance (Req) is the minimal. At this condition, the current flowing through the LED light string LED_1 is the maximal current (I_{LED_max}), that is the luminous brightness of the LED light string LED_1 is the brightest. On the contrary, if the branch switches Qrl-Qrn are all turned off by the corresponding branch control signals LED_CTRL_1-LED_CTRL_n, the equivalent resistance (Req) is the maximal, which is equal to the resistance of the designed resistor Rset (since the resistors Rset_1-Rest_n are turned off). At this condition, the current flowing through the LED light string LED_1 is the maximal is the minimal current (I_{LED_min}), that is the luminous brightness of the LED light string LED_1 is the darkest. Therefore, the branch switches Qrl-Qrn are controlled by the corresponding branch control signals LED_CTRL_1-LED_CTRL_n to be turned on and turned off so that the current flowing through the LED light string LED_1 is between the maximal current (I_{LED_max}) and the minimal current (I_{LED_mim}), thereby controlling the luminous brightness of the LED light string LED_1.

[0032] Furthermore, a duty cycle of the PWM signal LED PWM is controlled by the controller 100, such as duty cycle=1%, duty cycle=2%, ... and duty cycle=100%, and therefore the current flowing through the LED light string LED_1 can be finely adjusted by 1% intervals so that the high precision control of the current flowing through the LED light string LED_1 can be implemented.

[0033] In another embodiment, take more LED light strings (for example the first LED light string to the nth LED light string) shown in FIG. 4 as an example. The current control apparatus includes a plurality of light string switches Q1-Qn, a plurality of resistor branches Br_1-Br_n, and a controller 100.

[0034] The light string switches Q1-Qn are respectively coupled in series to the LED light strings LED_1-LED_n (as shown in FIG. 4), and a plurality of series-connected structures formed by the light string switches Q1-Qn and the LED light strings LED_1-LED_n are electrically coupled between an output end of a positive drive voltage V_{LED+} and an output end of a negative drive voltage V_{LED-}. The resistor branches Br_1-Br_n are electrically coupled to the LED light strings LED_1-LED_n (as shown in FIG. 3), that is, a set of resistor branches Br_1-Br_n are electrically coupled to one LED light string LED_1-LED_n, and the resistor branches Br_1-Br_n are electrically coupled to the output end of the negative drive voltage V_{LED-}. Each of the resistor branches Br_1-Br_n includes a resistor Rset_1-Rset_n and a branch switch Qr1-Qrn coupled in series to the resistor Rset_1-Rset_n.

[0035] The controller 100 provides a plurality of light string control signals LED_1_EN-LED_n_EN and a plurality of branch control signals LED_CTRL_1-LED_CTRL_n. The light string control signals LED_1_EN-LED_n_EN are used to respectively turn on and turn off the LED light strings LED_1-LED_n. For example, the light string control signal LED_1_EN is used to turn on and turn off the LED light string LED_1 by turning on and turning off the light string switch Q1, the light string control signal LED_2_EN is used to turn on and turn off the LED light string LED 2 by turning on and turning off the light string switch Q2, and so on. The branch control signals LED_CTRL_1-LED_CTRL_n are used to respectively turn on and turn off the branch switches Qrl-Qrn. For example, the branch control signal LED_CTRL_1 is used to turn on and turn off the branch switch Qr1, the branch control signal LED_CTRL_2 is used to turn on and turn off the branch switch Qr2, and so on.

[0036] For example, if a current flowing through the LED light string LED_1 and a current flowing through the LED light string LED_2 are controlled, the controller 100 provides the light string control signal LED_1_EN and the light string control signal LED_2_EN respective turn on the light string switch Q1 and the light string switch Q2 so that the LED light string LED_1 and the LED light string LED 2 are correspondingly driven by the positive drive voltage V_{LED+} and the negative drive voltage V_{LED-}.

[0037] For convenience and clarity, two LED light strings LED_1-LED_2 are used as examples. In particular, one of the two LED light strings LED_1-LED_2, i.e., the LED light string LED_1 is used as the fill light source 10 shown in FIG. 1 and the other of the two LED light strings LED_1-LED_2, i.e., the LED light string LED_2 is used as the makeup light source 20 shown in FIG. 1. Since the luminous brightness of the fill light source 10 and that of the makeup light source 20 are different in application, that is, the luminous brightness of the fill light source 10 is usually larger and the luminous brightness of the makeup light source 20 is smaller. Therefore, in this embodiment, it is explained that multiple (for example, two) LED light strings LED_1-LED_n can be controlled with different maximum currents (positively related to the luminous brightness).

[0038] For example, if the fill light source 10 (i.e., the LED light string LED_1) is controlled for luminous brightness adjustment, the controller 100 provides the light string control signal LED_1_EN to turn on the light string switch Q1 and provides the light string control signal LED_2_EN to turn off the light string switch Q2, and therefore the luminous brightness of the LED light string LED_1 is controlled (but the LED light string LED_2 is not controlled). Since the luminous brightness of the fill light source 10 is usually larger compared to the makeup light source 20, a larger number of branch switches Qrl-Qrn or branch switches Qr1-Qrn with a smaller resistance are turned on by the branch control signals LED_CTRL_1-LED_CTRL_n provided by the controller 100 so that the equivalent resistance (Req) is smaller. Therefore, according to the calculation of the following relationship, a larger current flowing through the LED light string LED_1, such as 928.14 mA can be acquired so that a larger maximal luminous brightness of the LED light string LED_1 can be implemented.

$$I_{LED}=\frac{V_{FB}}{R_{eq}}$$

[0039] Furthermore, a duty cycle of the PWM signal LED_PWM is controlled by the controller 100, such as duty cycle=1%, duty cycle=2%, ... and duty cycle=100%, and therefore the current flowing through the LED light string LED_1 can be finely adjusted by 1% (i.e., 9.2814 mA) intervals so that the high precision control of the current flowing through the LED light string LED_1 can be implemented.

[0040] For example, if the makeup light source 20 (i.e., the LED light string LED 2) is controlled for luminous brightness adjustment, the controller 100 provides the light string control signal LED_2_EN to turn on the light string switch Q2 and provides the light string control signal LED_1_EN to turn off the light string switch Q1, and therefore the luminous brightness of the LED light string LED_2 is controlled (but the LED light string LED_1 is not controlled). Since the luminous brightness of the makeup light source 20 is usually smaller compared to the fill light source 10, a smaller number of branch switches Qrl-Qrn or branch switches Qrl-Qrn with a larger resistance are turned on by the branch control signals LED_CTRL_1-LED_CTRL_n provided by the controller 100 so that the equivalent resistance (Req) is larger. Therefore, according to the calculation of the following relationship, a smaller current flowing through the LED light string LED_2, such as 387.51 mA can be acquired so that a smaller maximal luminous brightness of the LED light string LED_2 can be implemented.

$$I_{LED}=\frac{V_{FB}}{R_{eq}}$$

[0041] Furthermore, a duty cycle of the PWM signal LED_PWM is controlled by the controller 100, such as duty cycle=1%, duty cycle=2%, ... and duty cycle=100%, and therefore the current flowing through the LED light string LED_2 can be finely adjusted by 1% (i.e., 3.8751 mA) intervals so that the high precision control of the current flowing through the LED light string LED_2 can be implemented.

[0042] The current control of the LED light string LED_1 and the LED light string LED 2 is presented in the following tables.

Table 1

	selection of controlled LED light string(s)		selection of parallel-connected branch(es) (Rset)		parallel-connected resistance		equivalent resistance
mode	LED_1_EN	LED_2_EN	LED_CTRL_1	LED_CTRL_2	Rset_1	Rset_2	Req
1	0	0	0	0	0.167	0.4	N/A
2	0	1	0	1	0.167	0.4	0.4
3	1	0	1	0	0.167	0.4	0.167
4	1	1	1	1	0.167	0.4	0.1178

Table 2 (continued Table 1)

mode	the maximum current of the LED light string (mA) (I_{LED} max)	current range of the LED light string (mA)	current of each part (mA)
1	0	0	0
2	387.51	0-387.51	3.8751
3	928.14	0-928.14	9.2814
4	1316	0-1316	13.16

[0043] As disclosed in table 1 and table 2, when the fill light source 10 and the makeup light source 20 are not controlled for luminous brightness adjustment, the mode 1 is selected. Therefore, the light string control signal LED_1_EN and the light string control signal LED_2_EN are both logic low level (i.e., logic zero).

[0044] When the makeup light source 20 is controlled for luminous brightness adjustment (but the fill light source 10 is not), the mode 2 is selected. Therefore, the light string control signal LED_1_EN is logic low level but the light string control signal LED_2_EN is logic high level (i.e., logic one). As mentioned above, since the luminous brightness of the makeup light source 20 is usually smaller, a smaller number of branch switches Qrl-Qrn or branch switches Qrl-Qrn with a larger resistance are turned on by the branch control signals LED_CTRL_1-LED_CTRL_n provided by the controller 100. Accordingly, the branch control signal LED_CTRL_2 is selected to turn on the branch switch Qr2 with a larger resistance, that is, the branch control signal LED_CTRL_2 is logic high level but the branch control signal LED_CTRL_1 is logic low level (i.e., the branch switch Qr1 is turned off), therefore an equivalent resistance of 0.4 ohms is acquired. The maximum current flowing through the LED light string (I_{LED_max}) is 387.51 mA, which can be calculated by the relationship of the current flowing through the LED light string (I_{LED}) if the feedback voltage V_{FB} is assumed to 0.155 volts. Therefore, the controllable current range of the LED light string is 0 to 387.51 mA. Furthermore, if 1% intervals is divided, the current of each part is 3.8751 mA, and therefore the current flowing through the LED light string LED 2 can be finely adjusted.

[0045] When the fill light source 10 is controlled for luminous brightness adjustment (but the makeup light source 20 is not), the mode 3 is selected. Therefore, the light string control signal LED_1_EN is logic high level but the light string control signal LED_2_EN is logic low level. As mentioned above, since the luminous brightness of the fill light source 10 is usually larger, a larger number of branch switches Qrl-Qrn or branch switches Qrl-Qrn with a smaller resistance are turned on by the branch control signals LED_CTRL_1- LED_CTRL_n provided by the controller 100. Accordingly, the branch control signal LED_CTRL_1 is selected to turn on the branch switch Qr2 with a smaller resistance, that is, the branch control signal LED_CTRL_1 is logic high level but the branch control signal LED_CTRL_2 is logic low level (i.e., the branch switch Qr2 is turned off), therefore an equivalent resistance of 0.167 ohms is acquired. The maximum current flowing through the LED light string (I_{LED_max}) is 928.14 mA, which can be calculated by the relationship of the current flowing through the LED light string (I_{LED}) if the feedback voltage V_{FB} is assumed to 0.155 volts. Therefore, the controllable current range of the LED light string is 0 to 928.14 mA. Furthermore, if 1% intervals is divided, the current of each part is 9.2814 mA, and therefore the current flowing through the LED light string LED_1 can be finely adjusted.

[0046] When the fill light source 10 and the makeup light source 20 are both controlled for luminous brightness adjustment, the mode 4 is selected. Therefore, the light string control signal LED_1_EN and the light string control signal LED_2_EN are both logic high level. The branch control signal LED_CTRL_1 and the branch control signal LED_CTRL_1 controlled by the controller 100 are both logic high level, and therefore the branch switch Qr1 and the branch switch Qr2 are both turned on so that an equivalent resistance of parallel-connected Rset_1 and Rset_2 is 0.1178 ohms. The maximum current flowing through the LED light string (I_{LED_max}) is 1316 mA, which can be calculated by the relationship of the current flowing through the LED light string (I_{LED}) if the feedback voltage V_{FB} is assumed to 0.155 volts. Therefore, the controllable current range of the LED light string is 0 to 1316 mA. Furthermore, if 1% intervals is divided, the current of each part is 13.16 mA, and therefore the current flowing through the LED light string LED_1 and the current flowing through the LED light string LED 2 can be finely adjusted.

[0047] According to the above description, the current control apparatus with high precision control can be used to control (adjust) the luminous brightness of one or more LED light strings. According to the requirements of the application, the luminous brightness of the individual LED light string can be controlled, or the luminous brightness of the multiple LED light strings can be simultaneously controlled.

[0048] In conclusion, the present disclosure has following features and advantages:

1. The luminous brightness of the individual LED light string can be controlled, or the luminous brightness of the multiple LED light strings can be simultaneously controlled so as to increase the diversity and flexibility of light source control applications.
2. By using fewer light source drivers, it is possible to reduce equipment costs, reduce occupied area of the driver, and reduce difficulty of circuit control. At the condition, different operation modes can be used to provide different maximum current supply range according to different usage scenarios and different brightness requirements.
3. By controlling the duty cycle of the PWM signal, it can finely adjust the current flowing through the LED light string, such as by 1% intervals so that the high precision control of the current flowing through the LED light string can be implemented.

Claims

1. A current control apparatus with high precision control configured to provide a current control for an LED light string (LED_1), **characterized in that** the current control apparatus comprising:

a light string switch (Q1) coupled in series to the LED light string (LED_1),
a plurality of resistor branches (Br_1-Br_n) electrically coupled to the LED light string (LED_1), each of the resistor branches (Br_1-Br_n) comprising a resistor (Rset_1-Rset_n) and a branch switch (Qrl-Qrn) coupled in series to the resistor (Rset_1-Rset_n), and
a controller (100) configured to provide a light string control signal (LED_1_EN) and a plurality of branch control

signals (LED_CTRL_1-LED_CTRL_n),
wherein the light string control signal (LED_1_EN) is configured to turn on and turn off the LED light string (LED_1), and the branch control signals (LED_CTRL_1-LED_CTRL_n) are configured to respectively turn on and turn off the branch switches (Qr1-Qrn).

2. The current control apparatus with high precision control in claim 1, wherein the branch switches (Qrl-Qrn) are turned on and turned off to make the corresponding resistors (Rset 1-Rset n) electrically coupled in parallel so as to provide an equivalent resistance and determine a maximum current.

3. The current control apparatus with high precision control in claim 2, wherein when the branch switches (Qrl-Qrn) are all turned on, the equivalent resistance is minimal; when the branch switches (Qrl-Qrn) are all turned off, the equivalent resistance is maximal.

4. The current control apparatus with high precision control in claim 2, wherein the controller (100) is configured to control a duty cycle of a PWM signal to finely adjust the maximum current.

5. The current control apparatus with high precision control in claim 4, wherein the maximum current is finely adjusted by 1% intervals.

6. A current control apparatus with high precision control configured to provide a current control for a plurality of LED light strings (LED_1-LED_n), **characterized in that** the current control apparatus comprising:

a plurality of light string switches (Q1-Qn) respectively coupled in series to the LED light strings (LED_1-LED_n),
a plurality of resistor branches (Br_1-Br_n) electrically coupled to the LED light strings (LED_1-LED_n), each of the resistor branches (Br_1-Br_n) comprising a resistor (Rset_1-Rset_n) and a branch switch (Qrl-Qrn) coupled in series to the resistor (Rset_1-Rset_n), and
a controller (100) configured to provide a plurality of light string control signals (LED_1_EN-LED_n-EN) and a plurality of branch control signals (LED_CTRL_1-LED_CTRL_n),
wherein the light string control signals (LED_1_EN-LED_n-EN) are configured to respectively turn on and turn off the LED light strings (LED_1-LED_n), and the branch control signals (LED_CTRL_1-LED_CTRL_n) are configured to respectively turn on and turn off the branch switches (Qr1-Qrn).

7. The current control apparatus with high precision control in claim 6, wherein the branch switches (Qrl-Qrn) are turned on and turned off to make the corresponding resistors (Rset 1-Rset n) electrically coupled in parallel so as to provide an equivalent resistance and determine a maximum current.

8. The current control apparatus with high precision control in claim 7, wherein when the branch switches (Qrl-Qrn) are all turned on, the equivalent resistance is minimal; when the branch switches (Qrl-Qrn) are all turned off, the equivalent resistance is maximal.

9. The current control apparatus with high precision control in claim 7, wherein the controller (100) is configured to control a duty cycle of a PWM signal to finely adjust the maximum current.

10. The current control apparatus with high precision control in claim 9, wherein the maximum current is finely adjusted by 1% intervals.

11. The current control apparatus with high precision control in claim 6, wherein the current control apparatus is applied to an electric mirror (1), and one of the LED light strings (LED_1-LED_n) is used as a fill light source (10) and the other of the LED light strings is used as a makeup light source (20).

12. The current control apparatus with high precision control in claim 11, wherein a maximum current provided to the fill light source (10) is larger than a maximum current provided to the makeup light source (20).

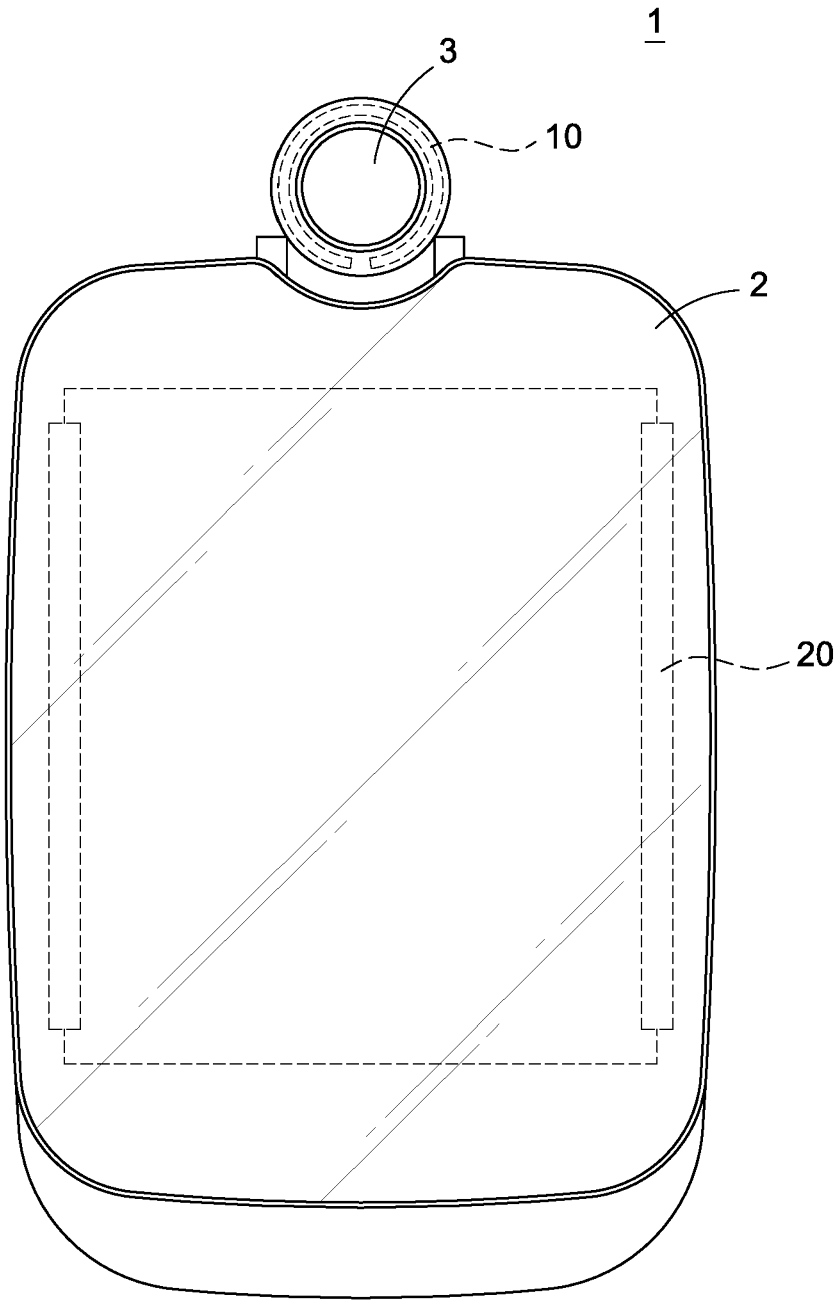
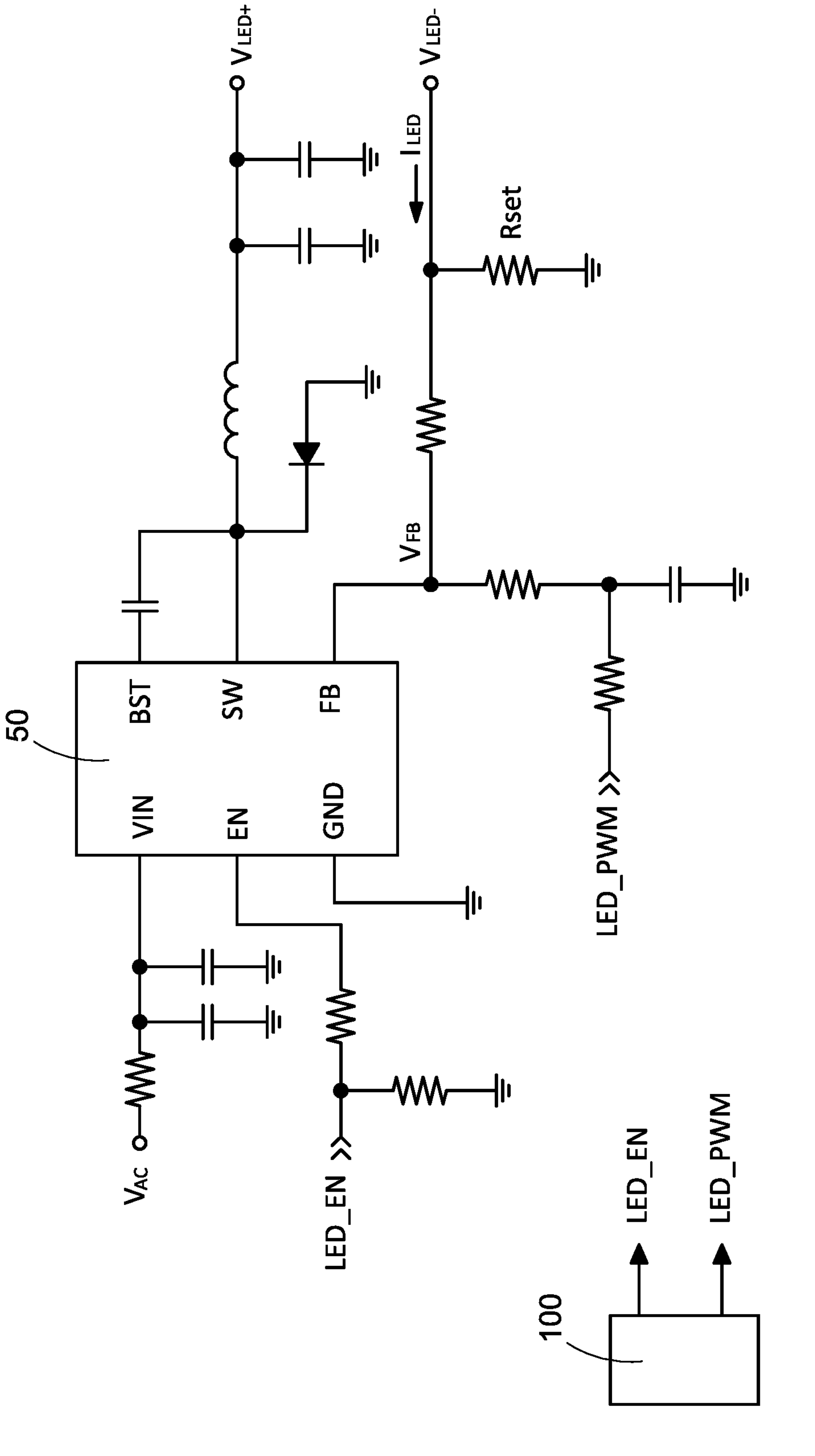


FIG.1



V_{LED+}
V_{LED-}
I_{LED}
Rset
V_{FB}
50
BST
SW
FB
VIN
EN
GND
V_{AC}
LED_EN
LED_PWM
100
LED_EN
LED_PWM

FIG.2

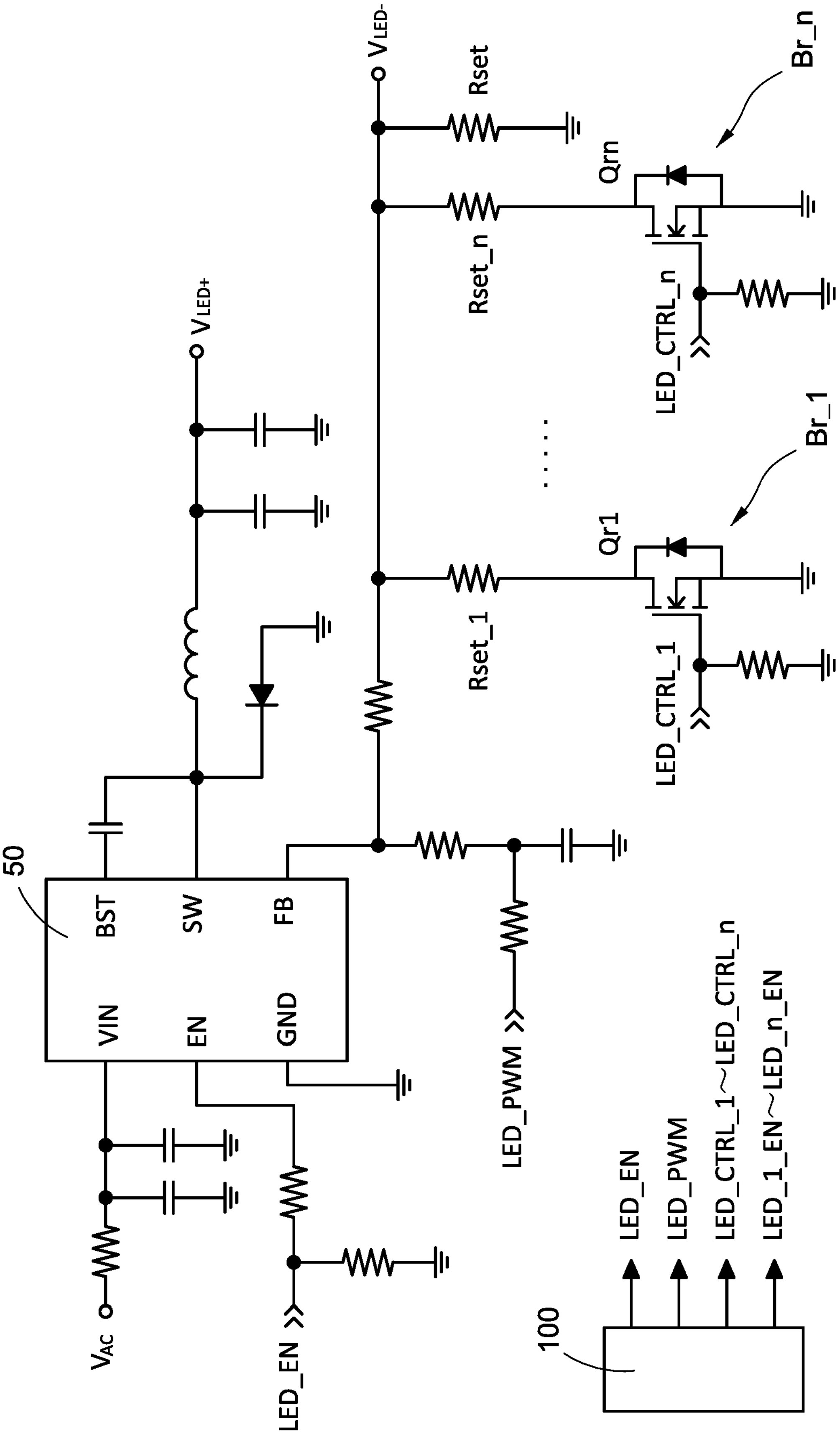

V_LED-
Rset
Br_n
Qrn
Rset_n
LED_CTRL_n
V_LED+
Br_1
Qr1
Rset_1
LED_CTRL_1
50
BST
SW
FB
VIN
EN
GND
LED_PWM
V_AC
LED_EN
100
LED_EN
LED_PWM
LED_CTRL_1~LED_CTRL_n
LED_1_EN~LED_n_EN

FIG.3

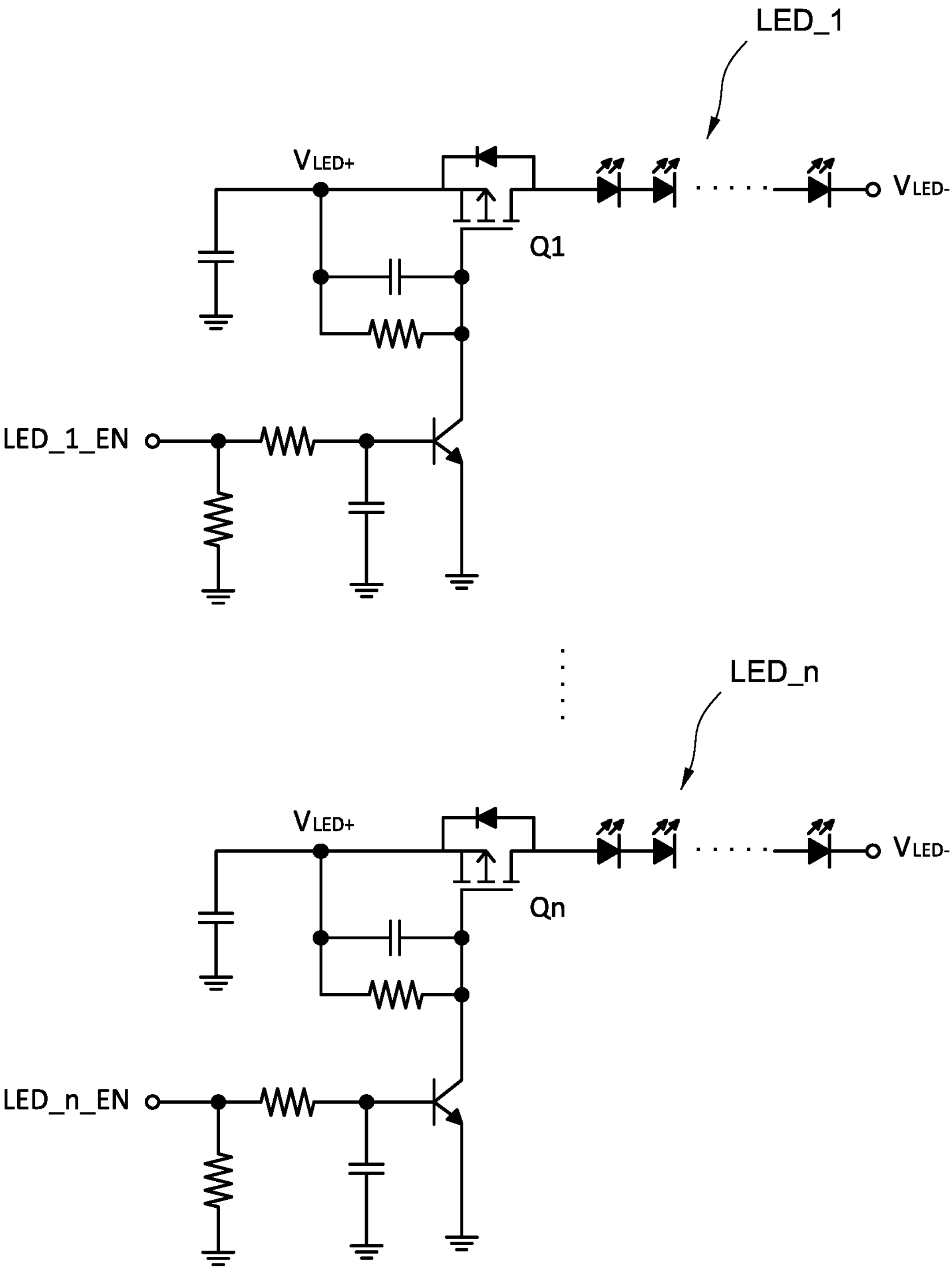


FIG.4

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EUROPEAN SEARCH REPORT

Application Number
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The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	13 January 2021	Henderson, Richard

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