(54) **METHOD FOR WIDE-RANGE CCT TUNING THAT FOLLOWS THE BLACK BODY LINE USING TWO INDEPENDENTLY CONTROLLED CURRENT CHANNELS AND THREE CCTS**

VERFAHREN ZUR WEITBEREICHS-CCT-ABSTIMMUNG, DIE DER SCHWARZKÖRPERLINIE UNTER VERWENDUNG VON ZWEI UNABHÄNGIG GESTEUERTEN STROMKANÄLEN UND DREI CCTS FOLGT

UN PROCÉDÉ DE SYNTONISATION CCT À LARGE GAMME QUI SUIT LA LIGNE DE CORPS NOIRAUXMOYEN DE DEUX CANAUX DE COURANT COMMANDÉS INDÉPENDAMMENT ET TROIS CCTS

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**Description**

**BACKGROUND**

5 **[0001]** Tunable white lighting is one of the biggest trends in commercial and home lighting. A tunable-white luminaire is usually able to change its color and light output level along two independent axes. DE 10 2012 207185 A1 discloses a device for producing white light whose color temperature can be adjusted, the device comprising: a first LED light source for generating a first light of a first color, a second LED light source for generating a second light of a second color, and a third LED light source for generating a third light of a third color. By appropriate brightness control of the 10 three LED light sources, a mixed light can be generated, the color point is virtually on the black body curve. US 2014/210368 A1 discloses an LED array including three or more strings of bare LEDs mounted in close proximity to each other on a substrate. The strings of LEDs emit light of one or more wavelengths of blue, indigo and/or violet light. A control circuit applies currents to the strings of LEDs, causing the LEDs in the strings to emit light, which causes the luminescent materials to emit light. A user interface enables users to control the currents applied by the control circuit 15 to the strings of LEDs to achieve a Correlated Color Temperature (CCT) value and hue that are desired by users, with CIE chromaticity coordinates that lie on, or near to the black body radiation curve. US 2014/333216 A1 discloses an apparatus that includes a first LED driver configured to control a first string of LEDs, a second LED driver configured to control a second string of LEDs, a third LED driver configured to control a third string of LEDs, and a control circuit configured to receive a control signal and to control the first, second, and third LED drivers so that the first, second, and 20 third strings of LEDs cooperate in producing light according to the control signal and a color curve.

**SUMMARY**

**[0002]** The method of the invention is defined by claim 1 and the device of the invention is defined by claim 7. Preferred 25 embodiments of the invention are defined by the dependent claims. An interface currents channeling circuit is used to convert two current channels of a conventional two-channel driver into three driving currents for the three LED arrays. By doing so, the same two channel driver may be used for applications requiring just two LED arrays as well as three LED arrays.

30 **BRIEF DESCRIPTION OF THE DRAWINGS**

**[0003]** A more detailed understanding may be had from the following description, given by way of example in conjunction with the accompanying drawings wherein:

35 FIG. 1 is a chromaticity diagram representing a color space;
FIG. 2 is a diagram illustrating different correlated color temperatures (CCTs) and their relationship to a black body line (BBL) on the chromaticity diagram;
FIG. 3 is a block diagram illustrating hardware used in a tunable white light engine having a corresponding number of light emitting diode (LED) arrays and driver channels;
40 FIG. 4 is a block diagram illustrating hardware used in tunable white light engine having a greater number of LED arrays than driver channels;
FIG. 5 is a circuit diagram of an interface currents channeling circuit; and
FIG. 6 is a flowchart illustrating a method for providing two-step linear CCT tunability in one or more LED arrays.

45 **DETAILED DESCRIPTION**

**[0004]** In the following description, numerous specific details are set forth, such as particular structures, components, materials, dimensions, processing steps, and techniques, in order to provide a thorough understanding of the present embodiments. It will be understood that when an element such as a layer, region, or substrate is referred to as being 50 "on" or "over" another element, it can be directly on the other element or intervening elements may also be present. In contrast, when an element is referred to as being "directly on" or "directly" over another element, there are no intervening elements present. It will also be understood that when an element is referred to as being "beneath," "below," or "under" another element, it can be directly beneath or under the other element, or intervening elements may be present. In contrast, when an element is referred to as being "directly beneath" or "directly under" another element, there are no 55 intervening elements present.
**[0005]** In the interest of not obscuring the presentation of embodiments in the following detailed description, some processing steps or operations that are known in the art may have been combined together for presentation and for illustration purposes and in some instances may have not been described in detail. In other instances, some processing

steps or operations that are known in the art may not be described at all. It should be understood that the following description is rather focused on the distinctive features or elements of various embodiments described herein.

[0006] Referring to FIG. 1, a chromaticity diagram representing a color space is shown. A color space is a three-dimensional space; that is, a color is specified by a set of three numbers that specify the color and brightness of a particular homogeneous visual stimulus. The three numbers may be the International Commission on Illumination (CIE) coordinates X, Y, and Z, or other values such as hue, colorfulness, and luminance. Based on the fact that the human eye has three different types of color sensitive cones, the response of the eye is best described in terms of these three "tristimulus values."

[0007] A chromaticity diagram is a color projected into a two-dimensional space that ignores brightness. For example, the standard CIE XYZ color space projects directly to the corresponding chromaticity space specified by the two chromaticity coordinates known as x and y, as shown in FIG. 1.

[0008] Chromaticity is an objective specification of the quality of a color regardless of its luminance. Chromaticity consists of two independent parameters, often specified as hue and colorfulness, where the latter is alternatively called saturation, chroma, intensity, or excitation purity. The chromaticity diagram may include all the colors perceivable by the human eye. The chromaticity diagram may provide high precision because the parameters are based on the spectral power distribution (SPD) of the light emitted from a colored object and are factored by sensitivity curves which have been measured for the human eye. Any color may be expressed precisely in terms of the two color coordinates x and y.

[0009] All colors within a certain region, known as a MacAdam ellipse (MAE) 102, may be indistinguishable to the average human eye from the color at the center 104 of the ellipse. The chromaticity diagram may have multiple MAEs. Standard Deviation Color Matching in LED lighting uses deviations relative to MAEs to describe color precision of a light source.

[0010] The chromaticity diagram includes the Planckian locus, or the black body line (BBL) 106. The BBL 106 is the path or locus that the color of an incandescent black body would take in a particular chromaticity space as the blackbody temperature changes. It goes from deep red at low temperatures through orange, yellowish white, white, and finally bluish white at very high temperatures. Generally speaking, human eyes prefer white color points not too far away from the BBL 106. Color points above the black body line would appear too green while those below would appear too pink.

[0011] One method of creating white light using light emitting diodes (LEDs) may be to additively mix red, green and blue colored lights. However, this method may require precise calculation of mixing ratios so that the resulting color point is on or close to the BBL 106. Another method may be to mix two or more phosphor converted white LEDs of different correlated color temperatures (CCTs). This method is described in additional detail below.

[0012] To create a tunable white light engine, LEDs having two different CCTs on each end of a desired tuning range may be used. For example, a first LED may have a CCT of 2700K, which is a warm white, and a second LED may have a color temperature of 4000K, which is a neutral white. White colors having a temperature between 2700K and 4000K may be obtained by simply varying the mixing ratio of power provided to the first LED through a first channel of a driver and power provided to the second LED through a second channel of the driver.

[0013] Referring now to FIG. 2, a diagram illustrating different CCTs and their relationship to the BBL 106 is shown. When plotted in the chromaticity diagram, the achievable color points of mixing two LEDs with different CCTs may form a first straight line 202. Assuming the color points of 2700K and 4000K are exactly on the BBL 106, the color points in between these two CCTs would be below the BBL 106. This may not be a problem, as the maximum distance of points on this line from the BBL 106 may be relatively small.

[0014] However, in practice, it may be desirable to offer a wider tuning range of color temperatures between, for example, 2700K and 6500K, which may be cool white or day light. If only 2700K LEDs and 6500K LEDs are used in the mixing, the first straight line 202 between the two colors may be far below the BBL 106. As shown in FIG. 2, the color point at 4000K may be very far away from the BBL 106.

[0015] To remedy this, a third channel of neutral white LEDs (4000K) may be added between the two LEDs and a 2-step tuning process may be performed. For example, a first step line 204 may be between 2700K and 4000K and a second step line 206 may be between 4000K and 6500K. This may provide 3 step MAE BBL color temperature tunability over a wide range of CCTs. A first LED array having a warm white (WW) CCT, a second LED array having a neutral white (NW) CCT, and a third LED array having a cool white (CW) CCT and a two-step tuning process may be used to achieve three-step MAE BBL CCT tunability over a wide range of CCTs.

[0016] Referring now to FIG. 3, a block diagram illustrating hardware used in a tunable white light engine having a corresponding number of LED arrays and driver channels is shown. As described above, a two channel driver 302 may be used to power two LED arrays having CCTs at the ends of a desired tuning range. The two channel driver 302 may be a conventional LED driver known in the art. The two LED arrays may be mounted on an LED board 318. A first channel 304 of the two channel driver 302 may power a first LED array 306 of a first CCT and a second channel 308 of the two channel driver 302 may power a second LED array 310 of a second CCT. The two channel driver 302 may provide two driving currents to the LED board 318 over one or more electrical connections 312, such as wires or direct board to board connections. The one or more electrical connections 312 may be connected to one or more solder points

316.

**[0017]** A three-channel driver may be used to control the three LED arrays in a similar manner. However, a three-channel driver may be more complex and expensive than a conventional two channel driver. It may be desirable to multiply the output of a driver to power a greater number of LED arrays than channels, such that there is more than a 1:1 ratio of driver channels to LED arrays.

**[0018]** Referring now to FIG. 4, a block diagram illustrating hardware used in tunable white light engine having a greater number of LED arrays than driver channels is shown. According to the invention, an interface currents channeling circuit is used to convert two current channels of a two channel driver 402 into three driving channels in order to achieve 2-piece linear near BBL 106 color temperature tunability.

**[0019]** In an embodiment, the interface currents channeling circuit may be mounted on a converter printed circuit board (PCB) 404 between the two channel driver 402 and a LED board 406. The two channel driver 302 may be a conventional LED driver known in the art. The interface currents channeling circuit may allow the two channel driver 402 to be used for applications requiring two LED arrays as well as applications with three LED arrays. Because the same two channel driver 402 may be used in both cases, circuit complexity, size, and expense may be reduced.

**[0020]** It should be noted that although FIG. 3 shows an interface channeling circuit that may be used to power three LED arrays using a two-channel driver, the principles described below may be applied to any arrangement in which a driver is used to power a number of LED arrays that is greater than a number of output channels. In addition, although the following description relates to the tunability of LED arrays having different CCTs, a person skilled in the art would understand that the embodiments described herein may apply to any desired tunable range, such as color ranges, infrared (IR) ranges, and ultraviolet (UV) ranges.

**[0021]** As described in more detail below, the interface currents channeling circuit mounted on the converter PCB 404 may enable the two channel driver 402 to power two LED arrays at the ends of a desired tunable range as well as an additional LED array in approximately the middle of the desired tunable range. A first LED array 408 having a first CCT, a second LED array 410 having a second CCT, and a third LED array 412 having a third CCT may be mounted on the LED board 318. A first channel 412 of the two channel driver 402 and a second channel 414 may be connected to the PCB 404 by a first set of connections 416, such as wires or direct board to board connections. The first channel 412 and the second channel 414 may each have a positive and a negative output.

**[0022]** The converter PCB 404 may provide three driving currents to the LED board 406 over a second set of electrical connections 418, such as wires or direct board to board connections. The second set of electrical connections 418 may be connected to one or more solder points 420 on the LED board 406. The second set of electrical connections 418 may include three separate negative outputs for the first LED array 408, the second LED array 410, and the third LED array 412. A LED+ output from the converter PCB 404 may be connected to a positive output of the two channel driver 402. The LED+ output may be connected to anode ends of the first LED array 408, the second LED array 410, and the third LED array 412.

**[0023]** The mathematical relationship between the inputs and outputs of the interface currents channeling circuit are described herein. In the following equations, a first input current may be I1 and a second input current may be 12. The output currents may be Iww for warm white (WW) LEDs, $I_{NW}$ for neutral white (NW) LEDs, and $I_{CW}$ for cool white (CW) LEDs. The relationship may be defined as follows:

If I1≥I2 then

$$I_{WW} = I1 - I2, \quad I_{NW} = 2 \times I2, \quad I_{CW} = 0 \qquad \text{Equation (1)}$$

Else

$$I_{WW} = 0, \quad I_{NW} = 2 \times I1, \quad I_{CW} = I2 - I1 \qquad \text{Equation (2)}$$

**[0024]** In the case of I1>I2, the WW channel may receive a current equal to the difference between I1 and 12, while the NW channel may receive twice the amount of current of I2. The sum of Iww and $I_{NW}$ may still be I1+I2. It should be noted that the actual sum may be slightly less than I1+I2 as part of the total current is used to power the interface currents channeling circuit.

**[0025]** If the current in I1 is 0 and I1 corresponds to the WW LEDs, all the current in 12 will go to the CW LEDs and no current will go to the WW LEDs or the NW LEDs. Likewise, if the current in 12 is 0 and 12 corresponds to the CW LEDs, all the current in I1 will go to the WW LEDs and no current will go to the CW LEDs or the NW LEDs.

**[0026]** Referring now to FIG. 5, a circuit diagram of the interface currents channeling circuit is shown. The interface currents channeling circuit makes use of various analog techniques, such as voltage sensing, low-pass filter and analog

signal subtraction. All voltages shown in the diagram refer to the ground. The converter PCB may control currents flowing through WW LEDs and CW LEDs using voltage controlled current sources. In addition, the converter PCB may perform only on/off control on current flowing through NW LEDs. The WW LEDs and the CW LEDs may have CCTs that are on the ends of a desired tunable range. The NW LEDs may have a CCT that is located approximately in the middle of the desired tunable range.

**[0027]** The first input current I1 may be connected to a first sense resistor (Rs) 502. The second input current 12 may be connected to a second Rs 504. The first Rs 502 and the second Rs 504 may have the same resistance value. A first diode D1 506 may prevent the first input current I1 from injecting into the second input current 12. A second diode D2 508 may prevent the second input current 12 from injecting into the first input current I1. The first Rs 502 and the second Rs 504 may share one common terminal $V_c$, which may be connected to the anodes of a first LED string 510 that includes WW LEDs, a second LED string 512 that includes NW LEDs, and a third LED string 514 that includes CW LEDs. The voltages at $V_a$ and Vb are representative of the currents flowing through the first Rs 502 and the second Rs 504 with a common-mode component, which is the voltage at $V_c$.

**[0028]** As shown in a first computational circuit 560, the voltage at $V_b$ may be attenuated by a resistive divider that includes a first resistor (R1) 516 and a second resistor (R2) 518. The resulting signal may be sent through a first low-pass filter (LPF) 520 to generate $V_{bb}$ in a low voltage domain. $V_{bb}$ may be defined as:

$$V_{bb} = LPF(V_b \times \alpha), \qquad \text{Equation (3)}$$

where $\alpha$ is an attenuation factor, which may be defined as:

$$\alpha = \frac{R2}{(R1+R2)}. \qquad \text{Equation (4)}$$

**[0029]** As shown in a second computational circuit 562, the voltage at $V_a$ may be attenuated by a resistive divider that includes a first resistor (R1) 522 and a second resistor (R2) 524. In an embodiment, the first resistor (R1) 522 may be the same value as the first resistor (R1) 516 and the second resistor (R2) may be the same value as the second resistor (R2) 518. The resulting signal may be sent through a second LPF 526 to generate $V_{aa}$ in a low voltage domain. In an embodiment, the second LPF 526 may perform the same operations as the first LPF 520. $V_{aa}$ may be defined as:

$$V_{aa} = LPF(V_a \times \alpha), \qquad \text{Equation (5)}$$

where $\alpha$ is the attenuation factor defined above in Equation (4).

**[0030]** $V_{bb}$ may be fed to a first operational amplifier (opamp) 528 that is configured to perform subtraction between $V_{bb}$ and $V_{aa}$. The outputs of the first opamp 528 may be Vww. Vww may be defined as:

$$V_{WW} = (V_{aa} - V_{bb}) \times \beta, \qquad \text{Equation (6)}$$

$$\text{where } \beta = R4/R3. \qquad \text{Equation (7)}$$

**[0031]** Vww may also be defined as:

$$V_{WW} = (I1 - I2) \times R_S \times \alpha \times \beta. \qquad \text{Equation (8)}$$

**[0032]** The current Iww may therefore be defined as:

$$I_{WW} = {V_{WW}}/{R} = (I1 - I2) \times \alpha \times \beta \times {R_S}/{R} \qquad \text{Equation (9)}$$

**[0033]** When $\alpha*\beta/R$ equals the value of 1/Rs, the current Iww will equal I1-I2.

**[0034]** $V_{aa}$ may be fed to a second opamp 530 that is configured to perform subtraction between $V_{aa}$ and $V_{bb}$. The

output of the second opamp 530 may be $V_{CW}$. $V_{CW}$ may be defined as:

$$V_{CW} = (V_{bb} - V_{aa}) \times \beta, \qquad \text{Equation (10)}$$

where $\beta$ is defined above in Equation (7). In an embodiment, R3 and R4 may have the same values in the first computational circuit 560 and the second computational circuit 562.

**[0035]** Vcw may also be defined as:

$$V_{CW} = (I2 - I1) \times R_S \times \alpha \times \beta. \qquad \text{Equation (11)}$$

**[0036]** The current Iww may therefore be defined as:

$$I_{CW} = {V_{CW}}/{R} = (I2 - I1) \times \alpha \times \beta \times {R_S}/{R} \qquad \text{Equation (12)}$$

**[0037]** When $\alpha^*\beta/R$ equals the value of 1/Rs, the current $I_{CW}$ will equal I2-I1.

**[0038]** The Vww may be fed to a voltage controlled current source, which may be implemented with a first amplifier (amp) 536. The first amp 536 may output a voltage $V_{g1}$. The voltage $V_{g1}$ may be input to a first transistor M1 that is used to provide a driving current for the first LED string 510. The first transistor M1 may be a conventional metal oxide semiconductor field effect transistor (MOSFET). The first transistor M1 may be an n-channel MOSFET.

**[0039]** The first amp 536 may regulate the voltage $V_{g1}$ in a closed loop such that current flowing through the first transistor M1 is equal to Vww/Rs. The inputs to the first amp 536 may be very close to each other in a closed loop regulation. The first amp 306 may compare the value of Vww to the sensed voltage across Rs 564 at the source of the first transistor M1. The Rs 564 may have the same resistance value as the first Rs 502 and/or the second Rs 504. If the sensed voltage is lower than Vww, the first amp 306 may raise $V_{g1}$ to increase the current in the first transistor M1 until the sensed voltage is approximately equal to $V_{WW}$. Likewise, if the sensed voltage is higher than Vww, the first amp 306 may reduce $V_{g1}$, which may reduce the current in the first transistor M1.

**[0040]** The Vcw may be fed to the voltage controlled current source, which may be implemented with a second amp 538. The second amp 538 may output a voltage $V_{g2}$. The voltage $V_{g2}$ may be input to a third transistor M3 that is used to provide a driving current for the third LED string 514. The third transistor M3 may be a conventional metal oxide semiconductor field effect transistor (MOSFET). The third transistor M3 may be an n-channel MOSFET.

**[0041]** The second amp 538 may regulate the voltage $V_{g2}$ in a closed loop such that current flowing through the third transistor M3 is equal to Vcw/Rs. The inputs to the second amp 538 may be very close to each other in a closed loop regulation. The second amp 538 may compare the value of Vcw to the sensed voltage across Rs 566 at the source of the third transistor M3. The Rs 566 may have the same resistance value as the first Rs 502 and/or the second Rs 504. If the sensed voltage is lower than Vcw, the second amp 538 may raise $V_{g2}$ to increase the current in the third transistor M3 until the sensed voltage is approximate equal to $V_{CW}$. Likewise, if the sensed voltage is higher than Vcw, the second amp 538 may reduce $V_{g2}$, which may reduce the current in the third transistor M3.

**[0042]** The output of the first amp 536 and the output of the second amp 538 may be clamped to zero when the difference between its inputs is negative.

**[0043]** A second transistor M2 may control power to the second LED string 512. The second transistor M2 may be a conventional metal oxide semiconductor field effect transistor (MOSFET). The second transistor M2 may be an n-channel MOSFET. The second transistor M2 may only be switched on when both the first input current I1 and the second input current I2 are in regulation. The second transistor M2 may have a pull up resistor (R7) 544 tied to Vc. The pull up resistor (R7) 544 may be tied to the node Vc because, at startup, the low voltage supply VDD may not be available. As a result, the first transistor M1 and the third transistor M3 would be in an off state. If the second transistor M2, which provides a driving current for the second LED string 512, is also off, the whole circuit would appear as open-circuit to the current sources. This may trigger open-circuit protection and lead to a non-startup condition. By tying the gate of M2 to the node Vc, it may provide a current path available at startup.

**[0044]** The current produced by the voltage controlled current sources for the first LED string 510 and the third LED string 514 may be slightly larger than the absolute value of (I1-I2). This may ensure that the second LED string 512 is off when either I1 or I2 carries zero current. In other words, only one string of LEDs at either endpoint of the desired tuning range may be on at a time.

**[0045]** The AND logic of the switching transistor may be realized by the gate control block 532. The gate control block 532 makes use of the fact that the output of the first amp 536 ($V_{g1}$) and the output of the second amp 538 ($V_{g2}$) in a

voltage controlled current source may swing to its supply rail (VDD) if it is unable to maintain regulation. The VDD may be chosen in such a way that the voltages $V_{g1}$ and $V_{g2}$ are significantly lower than VDD when the first amp 536 and the second amp 538 are in regulation under all operating conditions.

[0046] The $V_{g1}$ may be attenuated by resistive dividers that include a first resistor (R5) 540 and a second resistor (R6) 542, and then fed to a REF input of a first shunt regulator 570. The $V_{g2}$ may be attenuated by resistive dividers that include a first resistor (R5) 574 and a second resistor (R6) 576, and then fed to a REF input of a second shunt regulator 572. In an embodiment, the first resistor (R5) 540 and the second resistor (R6) 542 may be the same value as the first resistor (R5) 574 and the second resistor (R6) 576 $V_{g2}$. The first shunt regulator 570 and the second shunt regulator 572 may have an internal reference voltage of 2.5V. When the voltage applied at their REF nodes is higher than 2.5V, the first shunt regulator 570 and the second shunt regulator 572 may sink a large current. When the voltage applied at their REF nodes is lower than 2.5V, the first shunt regulator 570 and the second shunt regulator 572 may sink a very small quiescent current.

[0047] The large sinking current may pull the gate voltage of the second transistor M2 down to a level below its threshold, which may switch off the second transistor M2. The first shunt regulator 570 and the second shunt regulator 572 may not be able to pull their cathodes more than the $V_f$ of a diode below their REF nodes. Accordingly, the second transistor M2 may have a threshold voltage that is higher than 2V. Alternatively, a shunt regulator with a lower internal reference voltage, such as 1.5V, may be used.

[0048] If $V_{g1}$ and $V_{g2}$ would be maximum around 3V, the VDD may be set to be 5V and the attenuation factor $\alpha$ may be set to 0.6. When the first amp 536 and the second amp 538 are in regulation, the voltage appearing at the REF node of the shunt regulator would be a maximum of 1.8V, the shunt regulator may draw a minimum current and the gate of the second transistor M2 may be pulled high towards the VDD. If either the first amp 536 or the second amp 538 is out of regulation, the shunt regulator may switch off the NMOS.

[0049] It should be noted that well-known structures shown in FIG. 5, including one or more resistors, diodes, and capacitors, and processing steps have not been described in detail in order to avoid obscuring the embodiments described herein.

[0050] Referring now to FIG. 6, a flowchart illustrating a method for providing two-step linear CCT tunability in one or more LED arrays is shown. In step 602, the first input current I1 is received from the first channel 412 of the two channel LED driver 402. In step 604, a second input current I2 is received from the second channel 414 of the two channel LED driver 402. In step 606, a ratio of the first input current I1 to the second input current I2 is determined. In step 608, the first input current I1 and the second input current I2 are converted to a first output current, a second output current, and a third output current based on the ratio. In step 610, the first output current is provided to a first LED array 510 having a CCT at approximately an end of a desired CCT range, the second output current is provided to a second LED array 516 having a CCT at approximately an opposite end of the desired CCT range, and the third output current is provided to a third LED array 514 having a CCT in approximately a middle of a desired CCT range.

[0051] The method shown in FIG. 6 may be performed by the interface currents channeling circuit. The interface currents channeling circuit includes a first sense resistor 502 to sense a first input voltage from a first input current I2 from a first channel 412 of a two channel LED driver 402. A second sense resistor 504 senses a second input voltage of a second input current I2 from a second channel 414 of the two channel LED driver 402. The first sense resistor 502 and the second sense resistor 504 are tied to a common node $V_c$. A first computational circuit 560 is configured to subtract the second input voltage from the first input voltage to generate a first output voltage to power a first LED array 510 having a CCT at approximately an end of a desired CCT range. A second computational circuit 562 is configured to subtract the first input voltage from the second input voltage to generate a second output voltage to power a second LED array 516 having a CCT at approximately an opposite end of the desired CCT range. A gate control block 532 is configured to generate a third output voltage to power a third LED array 514 having a CCT in approximately a middle of a desired CCT range if the first input current I1 and the second input current 12 are both in regulation.

[0052] According to examples which do not fall under the scope of the present invention, the methods described herein may be implemented in a computer program, software, or firmware incorporated in a computer-readable medium for execution by a computer or processor. Examples of computer-readable media include electronic signals (transmitted over wired or wireless connections) and computer-readable storage media. Examples of computer-readable storage media include, but are not limited to, a read only memory (ROM), a random access memory (RAM), a register, cache memory, semiconductor memory devices, magnetic media such as internal hard disks and removable disks, magneto-optical media, and optical media such as CD-ROM disks, and digital versatile disks (DVDs).

**Claims**

1. A method of providing two-step linear spectral tunability in a light emitting diode (LED) device, the method comprising:

providing a first output current (Iww) to a first LED array (510) at approximately an end of a desired tunable spectral range, a second output current ($I_{CW}$) to a second LED array (514) at approximately an opposite end of the desired tunable spectral range, and a third output current ($I_{NW}$) to a third LED array (512) at approximately a middle of the desired tunable spectral range,

**characterized by** the steps of:

receiving a first input current (I1) from a first channel of a two channel LED driver (402);
receiving a second input current (I2) from a second channel of the two channel LED driver (402);
comparing the first input current (I1) to the second input current (I2) to determine a ratio, comprising detecting that the first input current (I1) is greater than or approximately equal to the second input current (I2) or that the second input current (I2) is greater than or approximately equal to the first input current (I1) ; and
converting the first input current (I1) and the second input current (I2) to the first output current (Iww), the second output current ($I_{CW}$), and the third output current ($I_{NW}$) based on the ratio,
wherein the first output current (Iww) is a difference between the first input current (I1) and the second input current (I2), the second output current ($I_{CW}$) is approximately zero, and the third output current ($I_{NW}$) is approximately twice the second input current (I2) when the first input current (I1) is greater than or approximately equal to the second input current (I2), and
wherein the first output current (Iww) is approximately zero, the second output current ($I_{CW}$) is the difference between the second input current (I2) and the first input current (I1), and the third output current ($I_{NW}$) is approximately twice the first input current (Iww) when the second input current (I2) is greater than or approximately equal to the first input current (I1).

2.  The method of claim 1, wherein the first LED array (510) has a correlated color temperature, CCT, at approximately the end of the desired tunable spectral range, the second LED array (514) has a CCT at approximately the opposite end of the desired tunable spectral range, and the third LED array (512) has a CCT at approximately the middle of the desired tunable spectral range.

3.  The method of claim 2, wherein the CCT of the first LED array (510), the CCT of the second LED array (514), and the CCT of the third LED (512) array are each located on the black body line, BBL.

4.  The method of claim 1, further comprising:

providing a positive output of the two channel driver (402) to anode ends of the first LED array (510), the second LED array (514), and the third LED array (512).

5.  The method of claim 1, wherein the third output current ($I_{NW}$) is provided to the third LED array (512) when the first input current (I1) and the second input current (I2) are active.

6.  The method of claim 1, wherein the first input current (I1) and the second input current (I2) are received by one or more circuits on a printed circuit board, PCB, (404).

7.  A light emitting diode (LED) device for providing two-step linear spectral tunability, the device comprising:

an interface currents channeling circuit (404);
a first LED array (510) at approximately an end of a desired tunable spectral range and configured to be powered by a first output voltage (Vww) of the interface currents channeling circuit (404);
a second LED array (514) at approximately an opposite end of the desired tunable spectral range and configured to be powered by a second output voltage ($V_{CW}$) of the interface currents channeling circuit (404); and
a third LED array (512) having at approximately a middle of the desired tunable spectral range and configured to be powered by a third output voltage of the interface currents channeling circuit (404),
**characterized in that**
the interface currents channeling circuit (404) comprises
a first sense resistor Rs (502) configured to sense a first input voltage ($V_a$) from a first input current (I1) from a first channel of a two channel LED driver (402):
a second sense resistor Rs (504) configured to sense a second input voltage ($V_b$) of a second input current (I2) from a second channel of the two channel LED driver (402), wherein the first sense resistor Rs (502) and the second sense resistor Rs (508) are tied to a common node;
a first computational circuit (560) configured to subtract the second input voltage ($V_b$) from the first input voltage

$(V_a)$ to control the first output voltage (Vww);

a second computational circuit (562) configured to subtract the first input voltage $(V_a)$ from the second input voltage $(V_b)$ to control the second output voltage (Vcw); and

a gate control circuit (532) configured to control the third output voltage if the first input current (I1) and the second input current (I2) are both active,

wherein a first output current (Iww) of the first LED array (510) is a difference between the first input current (I1) and the second input current (I2), a second output current $(I_{CW})$ of the second LED array (514) is approximately zero, and a third output current $(I_{NW})$ of the third LED array (512) is approximately twice the second input current (I2) when the first input current (I1) is greater than or approximately equal to the second input current (I2), and wherein the first output current (Iww) is approximately zero, the second output current $(I_{CW})$ is the difference between the second input current (I2) and the first input current (I1), and the third output current $(I_{NW})$ is approximately twice the first input current $(I_{WW})$ when the second input current (I2) is greater than or approximately equal to the first input current (I1).

8.  The device of claim 7, further comprising:

    a first amplifier (536) coupled to the first output voltage (Vww) and configured to provide a first gate voltage $(V_{g1})$ to a first transistor (M1); and
    a second amplifier (538) coupled to the second output voltage (Vcw) and configured to provide a second gate voltage $(V_{g2})$ to a second transistor (M3).

9.  The device of claim 7, further comprising:

    a first shunt regulator (570) in the gate control circuit (532) coupled to the first gate voltage $(V_{g1})$; and
    a second shunt regulator (572) in the gate control circuit (532) coupled to the second gate voltage $(V_{g2})$.

10. The device of claim 7, further comprising:

    a pull up resistor (544) coupled to the common node and the gate control circuit (532).

11. The device of claim 7, wherein the gate control circuit (532) is coupled to the common node, the first gate voltage $(V_{g1})$, the second gate voltage $(V_{g2})$, and a third transistor (M3).

12. The device of claim 7, wherein the first computational circuit (560) comprises:

    a first divided resistor R1 (516) configured to attenuate the second input voltage $(V_b)$;
    a first low pass filter (520) configured to filter the attenuated second input voltage (Vb); and
    a first operational amplifier (528).

13. The device of claim 7, wherein the second computational circuit (562) comprises:

    a second divided resistor R1 (522) configured to attenuate the first input voltage $(V_a)$;
    a second low pass filter (526) configured to filter the attenuated fist input voltage $(V_a)$; and
    a second operational amplifier (530).

14. The device of claim 7, wherein the first computational circuit (560) is configured to clamp the first output voltage (Vww) to approximately zero if the difference between the first input voltage $(V_a)$ and the second input voltage $(V_b)$ is negative.

15. The device of claim 7, wherein the second computational circuit (562) is configured to clamp the second output voltage to approximately zero if the difference between the second input voltage $(V_b)$ and the first input voltage $(V_a)$ is negative.

16. The device of claim 7, wherein the first LED array (510) has a correlated color temperature, CCT, at approximately the end of the desired tunable spectral range, the second LED array (514) has a CCT at approximately the opposite end of the desired tunable spectral range, and the third LED array (512) has a CCT at approximately the middle of the desired tunable spectral range.

**Patentansprüche**

1. Verfahren zum Bereitstellen einer zweistufigen, linearen, spektralen Abstimmbarkeit in einer Leuchtdio-den-(LED-)Vorrichtung, wobei das Verfahren Folgendes umfasst:

   Bereitstellen eines ersten Ausgangsstroms (Iww) für ein erstes LED-Array (510) an ungefähr einem Ende eines gewünschten abstimmbaren Spektralbereichs, eines zweiten Ausgangsstroms (Icw) für ein zweites LED-Array (514) an ungefähr einem gegenüberliegenden Ende des gewünschten abstimmbaren Spektralbereichs, und eines dritten Ausgangsstroms ($I_{NW}$) für ein drittes LED-Array (512) in ungefähr einer Mitte des gewünschten abstimmbaren Spektralbereichs,
   **gekennzeichnet durch** die folgenden Schritte:

   Empfangen eines ersten Eingangsstroms (I1) von einem ersten Kanal eines Zwei-Kanal-LED-Treibers (402),
   Empfangen eines zweiten Eingangsstroms (I2) von einem zweiten Kanal des Zwei-Kanal-LED-Treibers (402),
   Vergleichen des ersten Eingangsstroms (I1) mit dem zweiten Eingangsstrom (I2), um ein Verhältnis zu bestimmen, umfassend das Erkennen, dass der erste Eingangsstrom (I1) größer als oder ungefähr gleich dem zweiten Eingangsstrom (I2) ist oder dass der zweite Eingangsstrom (I2) größer als oder ungefähr gleich dem ersten Eingangsstrom (I1) ist, und
   Umwandeln des ersten Eingangsstroms (I1) und des zweiten Eingangsstroms (I2) in den ersten Ausgangs-strom (Iww), den zweiten Ausgangsstrom (Icw) und den dritten Ausgangsstrom ($I_{NW}$) basierend auf dem Verhältnis,
   wobei der erste Ausgangsstrom (Iww) eine Differenz zwischen dem ersten Eingangsstrom (I1) und dem zweiten Eingangsstrom (I2) ist, der zweite Ausgangsstrom (Icw) ungefähr null ist und der dritte Ausgangs-strom ($I_{NW}$) ungefähr das Zweifache des zweiten Eingangsstroms (I2) ist, wenn der erste Eingangsstrom (I1) größer als oder ungefähr gleich dem zweiten Eingangsstrom (I2) ist, und
   wobei der erste Ausgangsstrom (Iww) ungefähr null ist, der zweite Ausgangsstrom (Icw) die Differenz zwischen dem zweiten Eingangsstrom (I2) und dem ersten Eingangsstrom (I1) ist und der dritte Ausgangs-strom ($I_{NW}$) ungefähr das Zweifache des ersten Eingangsstroms (Iww) ist, wenn der zweite Eingangsstrom (I2) größer als oder ungefähr gleich dem ersten Eingangsstrom (I1) ist.

2. Verfahren nach Anspruch 1, wobei das erste LED-Array (510) eine korrelierte Farbtemperatur, CCT, an ungefähr dem Ende des gewünschten abstimmbaren Spektralbereichs aufweist, das zweite LED-Array (514) eine CCT an ungefähr dem gegenüberliegenden Ende des gewünschten abstimmbaren Spektralbereichs aufweist und das dritte LED-Array (512) eine CCT in ungefähr der Mitte des gewünschten abstimmbaren Spektralbereichs aufweist.

3. Verfahren nach Anspruch 2, wobei die CCT des ersten LED-Arrays (510), die CCT des zweiten LED-Arrays (514) und die CCT des dritten LED-Arrays (512) jeweils an der Schwarzkörperlinie, BBL, liegen.

4. Verfahren nach Anspruch 1, ferner umfassend:

   Bereitstellen eines positiven Ausgangs des Zwei-Kanal-Treibers (402) für Anodenenden des ersten LED-Arrays (510), des zweiten LED-Arrays (514) und des dritten LED-Arrays (512).

5. Verfahren nach Anspruch 1, wobei der dritte Ausgangsstrom ($I_{NW}$) für das dritte LED-Array (512) bereitgestellt wird, wenn der erste Eingangsstrom (I1) und der zweite Eingangsstrom (I2) aktiv sind.

6. Verfahren nach Anspruch 1, wobei der erste Eingangsstrom (I1) und der zweite Eingangsstrom (I2) durch einen oder mehrere Schaltkreise auf einer Leiterplatte, PCB, (404) empfangen werden.

7. Leuchtdioden-(LED-)Vorrichtung zum Bereitstellen einer zweistufigen, linearen, spektralen Abstimmbarkeit, wobei die Vorrichtung Folgendes umfasst:

   einen Schnittstellenströme-Kanalisierungsschaltkreis (404),
   ein erstes LED-Array (510) an ungefähr einem Ende eines gewünschten abstimmbaren Spektralbereichs und dazu gestaltet, durch eine erste Ausgangsspannung (Vww) des Schnittstellenströme-Kanalisierungsschaltkrei-ses (404) angetrieben zu werden,

ein zweites LED-Array (514) an ungefähr einem gegenüberliegenden Ende des gewünschten abstimmbaren Spektralbereichs und dazu gestaltet, durch eine zweite Ausgangsspannung (Vcw) des Schnittstellenströme-Kanalisierungsschaltkreises (404) angetrieben zu werden, und

ein drittes LED-Array (512), das in ungefähr einer Mitte des gewünschten abstimmbaren Spektralbereichs aufweist und dazu gestaltet, durch eine dritte Ausgangsspannung des Schnittstellenströme-Kanalisierungs-schaltkreises (404) angetrieben zu werden,

**dadurch gekennzeichnet, dass**

der Schnittstellenströme-Kanalisierungsschaltkreis (404) Folgendes umfasst:

einen ersten Messwiderstand Rs (502), der dazu gestaltet ist, eine erste Eingangsspannung ($V_a$) von einem ersten Eingangsstrom (I1) von einem ersten Kanal eines Zwei-Kanal-LED-Treibers (402) zu messen,

einen zweiten Messwiderstand Rs (504), der dazu gestaltet ist, eine zweite Eingangsspannung ($V_b$) eines zweiten Eingangsstroms (I2) von einem zweiten Kanal des Zwei-Kanal-LED-Treibers (402) zu messen, wobei der erste Messwiderstand Rs (502) und der zweite Messwiderstand Rs (508) an einen gemeinsamen Knoten gebunden sind,

einen ersten Rechenschaltkreis (560), der dazu gestaltet ist, die zweite Eingangsspannung ($V_b$) von der ersten Eingangsspannung ($V_a$) zu subtrahieren, um die erste Ausgangsspannung (Vww) zu steuern,

einen zweiten Rechenschaltkreis (562), der dazu gestaltet ist, die erste Eingangsspannung ($V_a$) von der zweiten Eingangsspannung ($V_b$) zu subtrahieren, um die zweite Ausgangsspannung (Vcw) zu steuern, und

einen Gate-Steuerschaltkreis (532), der dazu gestaltet ist, die dritte Ausgangsspannung zu steuern, wenn der erste Eingangsstrom (I1) und der zweite Eingangsstrom (I2) beide aktiv sind,

wobei der erste Ausgangsstrom (Iww) des ersten LED-Arrays (510) eine Differenz zwischen dem ersten Eingangsstrom (I1) und dem zweiten Eingangsstrom (I2) ist, ein zweiter Ausgangsstrom (Icw) des zweiten LED-Arrays (514) ungefähr null ist und ein dritter Ausgangsstrom ($I_{NW}$) des dritten LED-Arrays (512) un-gefähr das Zweifache des zweiten Eingangsstroms (I2) ist, wenn der erste Eingangsstrom (I1) größer als oder ungefähr gleich dem zweiten Eingangsstrom (I2) ist, und

wobei der erste Ausgangsstrom (Iww) ungefähr null ist, der zweite Ausgangsstrom (Icw) die Differenz zwischen dem zweiten Eingangsstrom (I2) und dem ersten Eingangsstrom (I1) ist und der dritte Ausgangs-strom ($I_{NW}$) ungefähr das Zweifache des ersten Eingangsstroms (Iww) ist, wenn der zweite Eingangsstrom (I2) größer als oder ungefähr gleich dem ersten Eingangsstrom (I1) ist.

8. Vorrichtung nach Anspruch 7, ferner umfassend:

einen ersten Verstärker (536), der mit der ersten Ausgangsspannung (Vww) gekoppelt und dazu gestaltet ist, eine erste Gate-Spannung ($V_{g1}$) für einen ersten Transistor (M1) bereitzustellen, und

einen zweiten Verstärker (538), der mit der zweiten Ausgangsspannung (Vcw) gekoppelt und dazu gestaltet ist, eine zweite Gate-Spannung ($V_{g2}$) für einen zweiten Transistor (M3) bereitzustellen.

9. Vorrichtung nach Anspruch 7, ferner umfassend:

einen ersten Shunt-Regler (570) in einem Gate-Steuerschaltkreis (532), der mit der ersten Gate-Spannung ($V_{g1}$) gekoppelt ist, und

einen zweiten Shunt-Regler (572) in dem Gate-Steuerschaltkreis (532), der mit der zweiten Gate-Spannung ($V_{g2}$) gekoppelt ist.

10. Vorrichtung nach Anspruch 7, ferner umfassend:

einen Pullup-Widerstand (544), der mit dem gemeinsamen Knoten und dem Gate-Steuerschaltkreis (532) ge-koppelt ist.

11. Vorrichtung nach Anspruch 7, wobei der Gate-Steuerschaltkreis (532) mit dem gemeinsamen Knoten, der ersten Gate-Spannung ($V_{g1}$), der zweiten Gate-Spannung ($V_{g2}$) und einem dritten Transistor (M3) gekoppelt ist.

12. Vorrichtung nach Anspruch 7, wobei der erste Rechenschaltkreis (560) Folgendes umfasst:

einen ersten geteilten Widerstand R1 (516), der dazu gestaltet ist, die zweite Eingangsspannung ($V_b$) zu dämp-fen,

ein erstes Tiefpassfilter (520), das dazu gestaltet ist, die gedämpfte zweite Eingangsspannung ($V_b$) zu filtern, und

einen ersten Operationsverstärker (528).

13. Vorrichtung nach Anspruch 7, wobei der zweite Rechenschaltkreis (562) Folgendes umfasst:

einen zweiten geteilten Widerstand R1 (522), der dazu gestaltet ist, die erste Eingangsspannung ($V_a$) zu dämpfen,
ein zweites Tiefpassfilter (526), das dazu gestaltet ist, die gedämpfte erste Eingangsspannung ($V_a$) zu filtern, und
einen zweiten Operationsverstärker (530).

14. Vorrichtung nach Anspruch 7, wobei der erste Rechenschaltkreis (560) dazu gestaltet ist, die erste Ausgangsspannung (Vww) auf ungefähr null festzustellen, wenn die Differenz zwischen der ersten Eingangsspannung ($V_a$) und der zweiten Eingangsspannung ($V_b$) negativ ist.

15. Vorrichtung nach Anspruch 7, wobei der zweite Rechenschaltkreis (562) dazu gestaltet ist, die zweite Ausgangsspannung auf ungefähr null festzustellen, wenn die Differenz zwischen der zweiten Eingangsspannung ($V_b$) und der ersten Eingangsspannung ($V_a$) negativ ist.

16. Vorrichtung nach Anspruch 7, wobei das erste LED-Array (510) eine korrelierte Farbtemperatur, CCT, an ungefähr dem Ende des gewünschten abstimmbaren Spektralbereichs aufweist, das zweite LED-Array (514) eine CCT an ungefähr dem gegenüberliegenden Ende des gewünschten abstimmbaren Spektralbereichs aufweist und das dritte LED-Array (512) eine CCT in ungefähr der Mitte des gewünschten abstimmbaren Spektralbereichs aufweist.

**Revendications**

1. Procédé qui permet d'assurer une accordabilité spectrale linéaire en deux étapes dans un dispositif à diode électroluminescente (LED), le procédé comprenant :

le fait de fournir un premier courant de sortie (Iww) à un premier réseau de LED (510) approximativement à une extrémité d'une plage spectrale réglable souhaitée, un second courant de sortie (Icw) à un second réseau de LED (514) approximativement à une extrémité opposée de la plage spectrale réglable souhaitée, et un troisième courant de sortie ($I_{NW}$) à un troisième réseau de LED (512) approximativement au centre de la plage spectrale réglable souhaitée, **caractérisé par** les étapes qui consistent à :

recevoir un premier courant d'entrée (I1) de la part d'un premier canal d'un excitateur de LED à deux canaux (402) ;
recevoir un second courant d'entrée (I2) de la part d'un second canal de l'excitateur de LED à deux canaux (402) ;
comparer le premier courant d'entrée (I1) avec le second courant d'entrée (I2) afin de déterminer un rapport, comprenant la détection du fait que le premier courant d'entrée (I1) soit supérieur ou approximativement égal au second courant d'entrée (I2) ou que le second courant d'entrée (I2) soit supérieur ou approximativement égal au premier courant d'entrée (I1) ; et
convertir le premier courant d'entrée (I1) et le second courant d'entrée (I2) en le premier courant de sortie (Iww), le second courant de sortie (Icw), et le troisième courant de sortie ($I_{NW}$) sur la base du rapport, dans lequel le premier courant de sortie (Iww) est une différence entre le premier courant d'entrée (I1) et le second courant d'entrée (I2), le second courant de sortie (Icw) est approximativement nul, et le troisième courant de sortie ($I_{NW}$) est approximativement deux fois supérieur au second courant d'entrée (I2) lorsque le premier courant d'entrée (I1) est supérieur ou approximativement égal au second courant d'entrée (I2), et dans lequel le premier courant de sortie (Iww) est approximativement nul, le second courant de sortie (Icw) est la différence entre le second courant d'entrée (I2) et le premier courant d'entrée (I1), et le troisième courant de sortie ($I_{NW}$) est approximativement deux fois supérieur au premier curant d'entrée (Iww) lorsque le second courant d'entrée (I2) est supérieur ou approximativement égal au premier courant d'entrée (I1).

2. Procédé selon la revendication 1, dans lequel le premier réseau de LED (510) possède une température de couleur corrélée, CCT, approximativement à l'extrémité de la plage spectrale réglable souhaitée, le second réseau de LED (514) possède une CCT approximativement à l'extrémité opposée de la plage spectrale réglable souhaitée, et le troisième réseau de LED (512) possède une CCT approximativement au centre de la plage spectrale réglable souhaitée.

**3.** Procédé selon la revendication 2, dans lequel la CCT du premier réseau de LED (510), la CCT du second réseau de LED (514), et la CCT du troisième réseau de LED (512) sont chacune situées sur la ligne de corps noir, BBL.

**4.** Procédé selon la revendication 1, comprenant en outre :

le fait de fournir une sortie positive de l'excitateur à deux canaux (402) aux extrémités d'anode du premier réseau de LED (510), du second réseau de LED (514), et du troisième réseau de LED (512).

**5.** Procédé selon la revendication 1, dans lequel le troisième courant de sortie ($I_{NW}$) est fourni au troisième réseau de LED (512) lorsque le premier courant d'entrée (I1) et le second courant d'entrée (I2) sont actifs.

**6.** Procédé selon la revendication 1, dans lequel le premier courant d'entrée (I1) et le second courant d'entrée (I2) sont reçus par un ou plusieurs circuit(s) sur une carte de circuit imprimé, PCB, (404).

**7.** Dispositif à diode électroluminescente (LED) destiné à assurer une accordabilité spectrale linéaire en deux étapes, le dispositif comprenant :

un circuit de répartition de courants d'interface (404) ;
un premier réseau de LED (510) approximativement à une extrémité d'une plage spectrale réglable souhaitée et configuré pour être alimenté par une première tension de sortie (Vww) du circuit de répartition de courants d'interface (404) ;
un second réseau de LED (514) approximativement à une extrémité opposée de la plage spectrale réglable souhaitée et configuré pour être alimenté par une seconde tension de sortie (Vcw) du circuit de répartition de courants d'interface (404) ; et
un troisième réseau de LED (512) approximativement au centre de la plage spectrale réglable souhaitée et configuré pour être alimenté par une troisième tension de sortie du circuit de répartition de courants d'interface (404),
**caractérisé en ce que**
le circuit de répartition de courants d'interface (404) comprend
une première résistance de détection Rs (502) configurée pour détecter une première tension d'entrée ($V_a$) à partir d'un premier courant d'entrée (I1) qui provient d'un premier canal d'un excitateur de LED à deux canaux (402) ;
une seconde résistance de détection Rs (504) configurée pour détecter une seconde tension d'entrée ($V_b$) d'un second courant d'entrée (I2) qui provient d'un second canal de l'excitateur de LED à deux canaux (402), dans lequel la première résistance de détection Rs (502) et la seconde résistance de détection Rs (508) sont associées à un nœud commun ;
un premier circuit de calcul (560) configuré pour soustraire la seconde tension d'entrée ($V_b$) de la première tension d'entrée ($V_a$) afin de contrôler la première tension de sortie (Vww) ;
un second circuit de calcul (562) configuré pour soustraire la première tension d'entrée ($V_a$) de la seconde tension d'entrée ($V_b$) afin de contrôler la seconde tension de sortie (Vcw) ; et
un circuit de commande de grille (532) configuré pour contrôler la troisième tension de sortie si le premier courant d'entrée (I1) et le second courant d'entrée (I2) sont actifs,
dans lequel un premier courant de sortie (Iww) du premier réseau de LED (510) est une différence entre le premier courant d'entrée (I1) et le second courant d'entrée (I2), un second courant de sortie (Icw) du second réseau de LED (514) est approximativement nul, et un troisième courant de sortie ($I_{NW}$) du troisième réseau de LED (512) est approximativement deux fois supérieur au second courant d'entrée (I2) lorsque le premier courant d'entrée (I1) est supérieur ou approximativement égal au second courant d'entrée (I2), et
dans lequel le premier courant de sortie (Iww) est approximativement nul, le second courant de sortie (Icw) est la différence entre le second courant d'entrée (I2) et le premier courant d'entrée (I1), et le troisième courant de sortie ($I_{NW}$) est approximativement deux fois supérieur au premier courant d'entrée (Iww) lorsque le second courant d'entrée (I2) est supérieur ou approximativement égal au premier courant d'entrée (I1).

**8.** Dispositif selon la revendication 7, comprenant en outre :

un premier amplificateur (536) couplé à la première tension de sortie (Vww) et configuré pour fournir une première tension de grille ($V_{g1}$) à un premier transistor (M1); et
un second amplificateur (538) couplé à la seconde tension de sortie (Vcw) et configuré pour fournir une seconde tension de grille ($V_{g2}$) à un second transistor (M3).

**9.** Dispositif selon la revendication 7, comprenant en outre :

un premier régulateur shunt (570) dans le circuit de commande de grille (532) couplé à la première tension de grille ($V_{g1}$) ; et
un second régulateur shunt (572) dans le circuit de commande de grille (532) couplé à la seconde tension de grille ($V_{g2}$).

**10.** Dispositif selon la revendication 7, comprenant en outre :

une résistance de polarisation à l'alimentation (544) couplée au nœud commun et au circuit de commande de grille (532).

**11.** Dispositif selon la revendication 7, dans lequel le circuit de commande de grille (532) est couplé au nœud commun, à la première tension de grille ($V_{g1}$), à la seconde tension de grille ($V_{g2}$) et à un troisième transistor (M3).

**12.** Dispositif selon la revendication 7, dans lequel le premier circuit de calcul (560) comprend :

une première résistance divisée R1 (516) configurée pour atténuer la seconde tension d'entrée ($V_b$) ;
un premier filtre passe-bas (520) configuré pour filtrer la seconde tension d'entrée atténuée ($V_b$) ; et
un premier amplificateur opérationnel (528).

**13.** Dispositif selon la revendication 7, dans lequel le second circuit de calcul (562) comprend :

une seconde résistance divisée R1 (522) configurée pour atténuer la première tension d'entrée ($V_a$) ;
un second filtre passe-bas (526) configuré pour filtrer la première tension d'entrée atténuée ($V_a$) ; et
un second amplificateur opérationnel (530).

**14.** Dispositif selon la revendication 7, dans lequel le premier circuit de calcul (560) est configuré pour figer la première tension de sortie (Vww) sur approximativement zéro si la différence entre la première tension d'entrée ($V_a$) et la seconde tension d'entrée ($V_b$) est négative.

**15.** Dispositif selon la revendication 7, dans lequel le second circuit de calcul (562) est configuré pour figer la seconde tension de sortie sur approximativement zéro si la différence entre la seconde tension d'entrée ($V_b$) et la première tension d'entrée ($V_a$) est négative.

**16.** Dispositif selon la revendication 7, dans lequel le premier réseau de LED (510) possède une température de couleur corrélée, CCT, approximativement à l'extrémité de la plage spectrale réglable souhaitée, le second réseau de LED (514) possède une CCT approximativement à l'extrémité opposée de la plage spectrale réglable souhaitée, et le troisième réseau de LED (512) possède une CCT approximativement au centre de la plage spectrale réglable souhaitée.

FIG. 1

FIG. 2

**FIG. 3**

302

312

304 Group 1 { + , - }

308 Group 2 { + , - }

316

316

306 310 306 318 310 306

310

316

**FIG. 4**

402

416

412 Group 1 { + , - }

414 Group 2 { + , - }

404 Converter PCB

LED1+
LED1-
LED2+
LED2-

2700K-
4000K-
6500K-
LED+

418

420

408 412 410

420

420 408 410 412

408 410 412

406

FIG. 5

```
┌─────────────────────────────────────────┐
│  Receive first input current from first   │
│       channel                             │───602
│      of two channel driver                │
└─────────────────────────────────────────┘
                    │
                    ▼
┌─────────────────────────────────────────┐
│  Receive second input current from second │
│       channel of two channel driver       │───604
└─────────────────────────────────────────┘
                    │
                    ▼
┌─────────────────────────────────────────┐
│  Determine a ratio of the first input     │
│       current to                          │───606
│      the second input current            │
└─────────────────────────────────────────┘
                    │
                    ▼
┌─────────────────────────────────────────┐
│  Convert the first input current and the  │
│   second input current to a first output  │
│   current, a second output current, and   │───608
│   a third output current based on the     │
│              ratio                        │
└─────────────────────────────────────────┘
                    │
                    ▼
┌─────────────────────────────────────────┐
│  Provide first output current to first    │
│   LED array, second output current to     │
│   second LED array, and third output      │───610
│   current to third LED array              │
└─────────────────────────────────────────┘
```
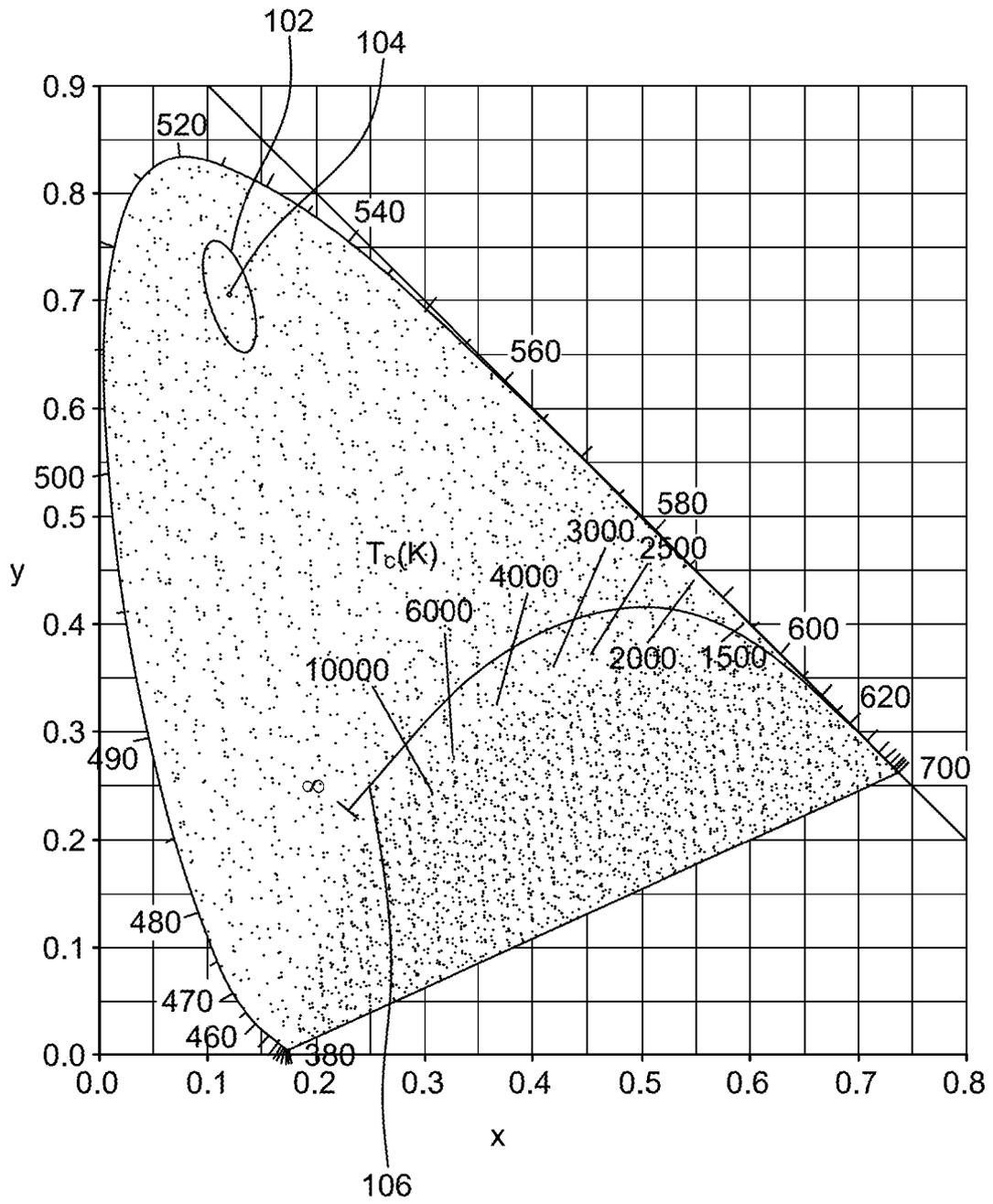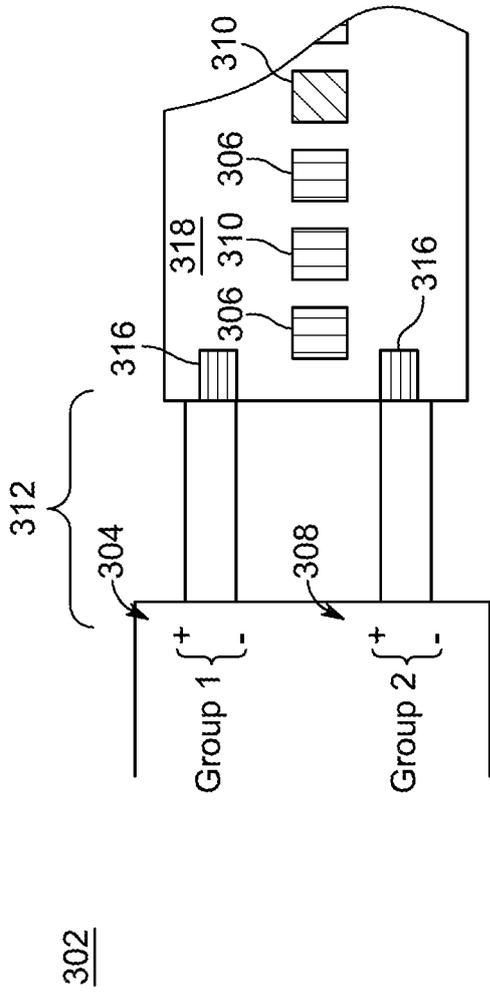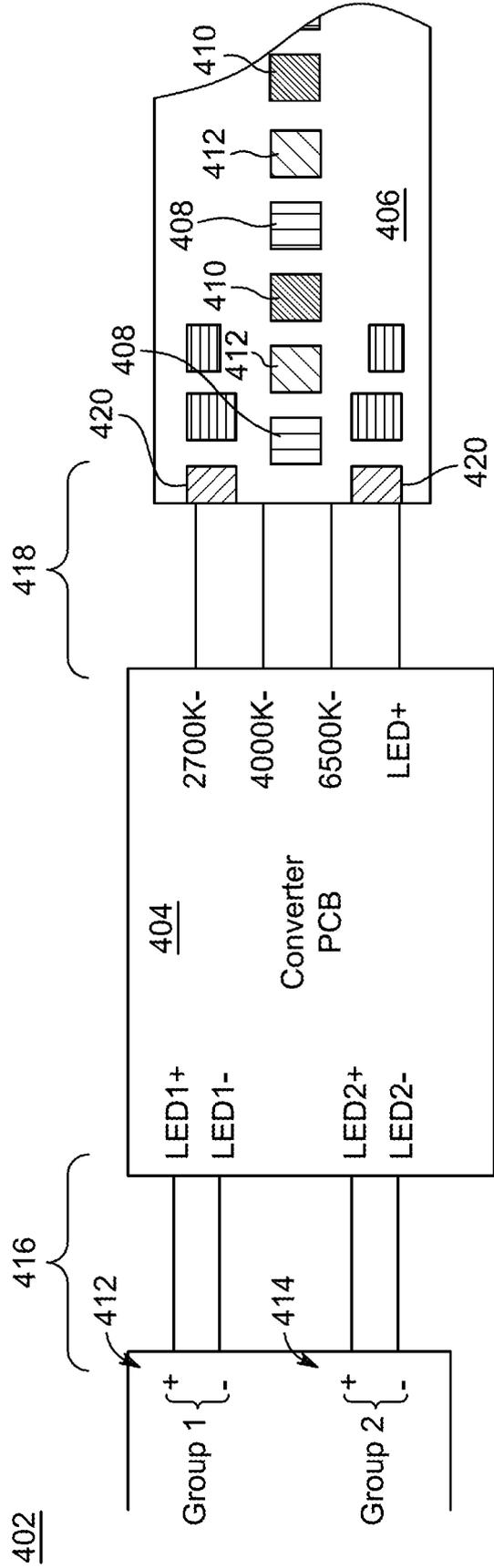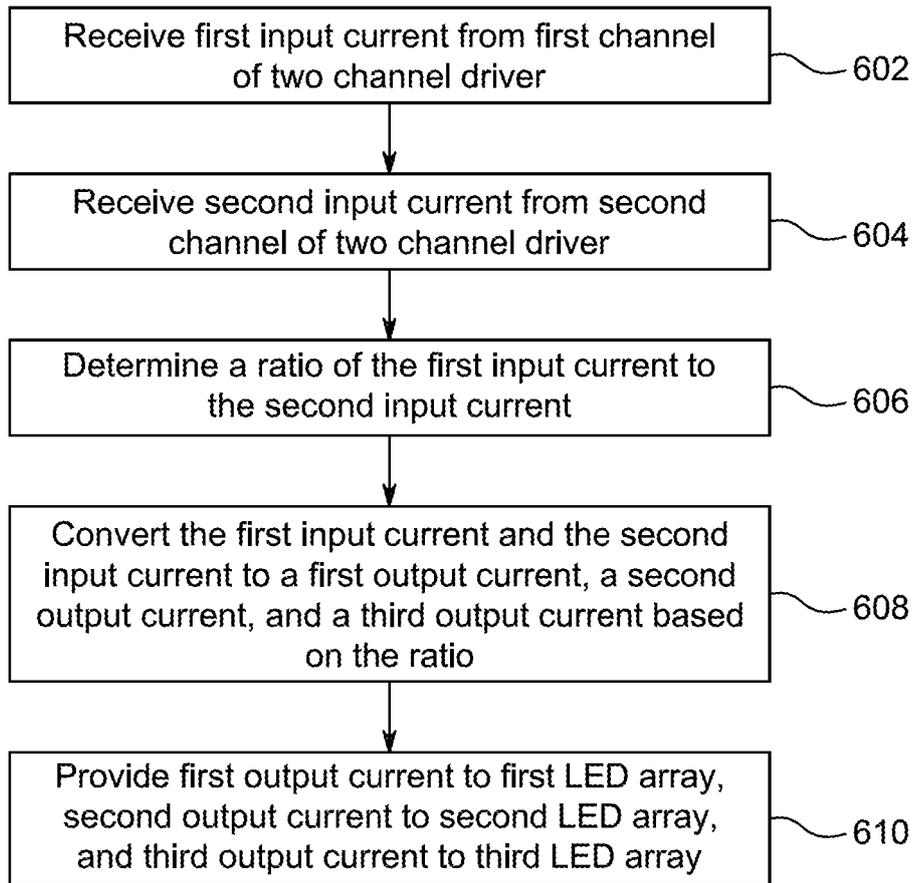
# FIG. 6

**REFERENCES CITED IN THE DESCRIPTION**

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**Patent documents cited in the description**

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