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(71) Applicants:
- **Valeo Vision**
  93012 Bobigny Cedex (FR)
- **University of Granada**
  Granada (ES)

(72) Inventors:
- **MARTINEZ-PEREZ, Jose-Ramon**
  93012 BOBIGNY CEDEX (FR)
- **SANTAELLA, Juan-Jose**
  93012 BOBIGNY CEDEX (FR)
- **CARVAJAL, Miguel**
  GRANADA (ES)
- **Martínez, Antonio**
  GRANADA (ES)

(74) Representative: **Cabinet Camus Lebkiri**
25 rue de Maubeuge
75009 Paris (FR)

(54) **LIGHTING CIRCUIT FOR AN AUTOMOTIVE LIGHTING DEVICE PRODUCING A CONSTANT LEVEL OF LUMINOUS FLUX**

(57) An aspect of the invention concerns a lighting circuit for an automotive lighting device, the lighting circuit comprising a plurality of light sources being configured to produce a level of a luminous flux,an integrated circuit being configured to supply a driving current to bias the level of the luminous flux of at least one light source of the plurality of light sources, and a compensation circuit connected with the integrated circuit. The compensation circuit being configured to modify an intensity of the electric current driving the at least one light source of the plurality of light sources, a level of the modification of the electric current being dependent on a detected variation of temperature of the at least one light source of the plurality of light sources. Based on the detected variation of the temperature of the at least one light source of the plurality of light sources, the level of the luminous flux is maintained within a range of luminous flux levels.

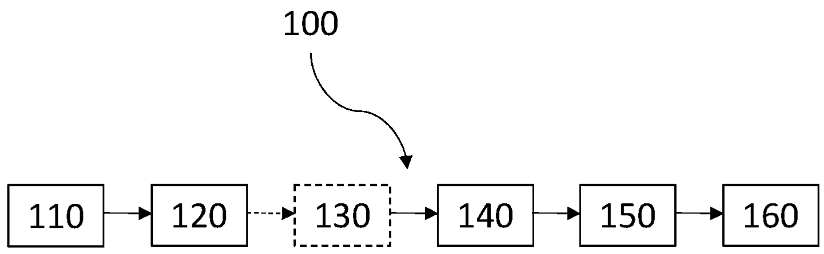

Fig. 2

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Description

TECHNICAL FIELD

[0001] The technical field of the invention is the one of automotive lighting.
[0002] The present invention regards a lighting circuit for an automotive lighting device producing a constant level of luminous flux independently of the temperature and a method for controlling a level of a luminous flux produced by at least one light source of a plurality of light sources.

STATE OF THE ART

[0003] Automotive lighting comprises all illumination functions that can be found on motor vehicles, which includes both interior and exterior lighting. Exterior lighting covers front, rear and signalling illumination. While automotive headlamps are intended to illuminate the forward scenario when visibility conditions are reduced, for example at night or under intense rain or fog, rear and signalling lights are used to provide optical communication with other traffic participants in order to increase safety.
[0004] Commercial solid state light emitting devices such as Light Emitting Diodes (LEDs), are commonly used in automotive lighting applications. It is also known to use commercially available integrated current drivers for automotive lighting applications. The integrated current driver forces a constant current through the light source over a wide temperature and operating voltage ranges to allow simple and easy operation of one or more light sources in low-power applications with driving currents from 10 to 150 milliamperes (mA), thus avoiding complex designs with discrete components. A current driver regulates the current flowing through the light source. An integrated current driver is a current driver integrated in an integrated circuit. The integrated circuit is a set of electronic circuits on one small flat piece, also known as a "chip", of semiconductor material. An integrated circuit for automotive lighting applications may comprise various components such as resistors, Negative Temperature Coefficient thermistors, noted NTC in the present application, or Positive Temperature Coefficient thermistors, noted PTC in the present application. Using commercially available components such as integrated current drivers and/or resistors and/or NTC and/or PTC is a strong prerequisite for this invention.
[0005] These commercial light sources have a luminous flux thermal dependence which may be important. In other words, the level of the luminous flux produced by the light source is dependent on the temperature. In the present patent application, the term "temperature" is used for the junction temperature and/or the ambient temperature of the automotive lighting component. The junction temperature is the temperature of the active region of the light source. The ambient temperature is the temperature around the light source. The temperature is increased by the functioning of the light source and by other sources of heating such as the driving electronics and light conversion elements.
[0006] Main mechanisms that lead to the decrease of efficiency of the light output are related to the non-radiative recombination through the well-known processes of Shockley-Read-Hall recombination and Auger recombination. However, each model of light source has a specific curve of levels of the luminous flux produced for a range of temperatures. The curve characterizing the level of the luminous flux produced by the light source according to the temperature will be noted, in the present application, the thermal drift signature curve of a light source. The thermal drift signature curve of a light source is dependent on the technology of the light source and especially on the semiconductor material used as active material. For example, a light source such as a Nichia™ NFSW172AT uses a first technology based on Gallium Nitride (GaN) and light sources such as Dominant™ DWA MKG and Dominant™ DWY MKG use a second technology based on a quaternary alloy $(Al_xGa_{1-x})_{0.5}In_{0.5}P$. Figure 1 shows an example of luminous fluxes produced by 3 light sources for a range of a junction temperature comprised between -40 degrees Celsius (°C) and +70 °C and for various intensities of the current driving the LED. As shown in figure 1, the level of the luminous flux produced by the light source is also dependent on the intensity of the electrical current driving the light source.
[0007] Special interest is devoted to maintaining a stable emitted light. Light sources in automotive lighting must be designed to meet the colour and luminosity limits established in the applying normative. In particular, the technical specifications for signal lights in automotive lighting, which include rear-registration plate illuminating lamps, direction indicator lamps, position lamps, stop lamps, end-outline marker lamps, reversing lamps, manoeuvring lamps, rear fog lamps, parking lamps, daytime running lamps and side marker lamps in the member countries of the United Nations Economic Commission for Europe (UNECE) are detailed in the UN Regulation No. 148 (United Nations, Agreement Concerning the Adoption of Harmonized Technical United Nations Regulations for Wheeled Vehicles, Equipment and Parts which can be Fitted and/or be Used on Wheeled Vehicles and the Conditions for Reciprocal Recognition of Approvals Granted on the Basis of these United Nations Regulations, Revision 3, 9 January 2020). Since the emitted light flux and the peak wavelength of a light source depend on the ambient temperature (E. Fred Schubert, Junction and carrier temperatures, in Light-Emitting Diodes, second edition, Cambridge, Cambridge University Press, 2006), some works have been aimed at correcting not only the junction temperature but also the drifts of the luminous flux due to changes in

ambient temperature. For example, the US patent US01048507SB2 discloses a system to switch between two discrete currents depending on a certain temperature threshold to increment the light source's bias current when temperature rises. The French patent application FR3096759A1 discloses a system to increment the bias current using discrete values when the light flux drops under a threshold. Both systems require a flux detector and the logic to switch the bias current in discrete steps. Then, a microcontroller has been included in the design in order to process the flux measurement and modify the bias current in consequence. These systems are therefore complex and of considerable size.

[0008] There is therefore a need to provide a lighting circuit for an efficient automotive lighting device producing a constant level of luminous flux independently of the temperature. Furthermore, this lighting circuit device needs to be compact and preferably built with commercially available components.

SUMMARY OF THE INVENTION

[0009] According to a first aspect of the invention, this need is satisfied by providing a lighting circuit for an automotive lighting device, the lighting circuit comprising:

- a plurality of light sources being configured to produce a level of a luminous flux,
- an integrated circuit being configured to supply a driving current to bias the level of the luminous flux of at least one light source of the plurality of light sources, and
- a compensation circuit connected with the integrated circuit, the compensation circuit being configured to modify an intensity of the electric current driving the at least one light source of the plurality of light sources, a level of the modification of the electric current being dependent on a detected variation of temperature of the at least one light source of the plurality of light sources, and

wherein, based on the detected variation of the temperature of the at least one light source of the plurality of light sources, the level of the luminous flux is maintained within a range of luminous flux levels.

[0010] The invention provides a lighting circuit for an automotive lighting device producing a constant level of luminous flux independently of the temperature by using an integrated circuit with a specifically designed thermal model. The term "thermal model" means, in the present application, that the lighting circuit modifies the intensity of the current driving the light sources according to the temperature. The compensation circuit provides an input to the integrated circuit. Based on the input from the compensation circuit, the integration circuit modifies the intensity of electric current driving the light sources which compensates the variations of the level of the luminous flux of the light sources due to the variations of the value of the temperature of the automotive lighting component. The integrated circuit of the designed automotive lighting component is specific to the characteristics of the LED. Especially, the thermal model of the integrated circuit is specific to the thermal drift signature curve of the light emitting diode. Therefore, the lighting circuit ensures that the luminous flux produced by the light emitting diode is maintained within a range of luminous flux levels, irrespective of the value of the temperature variations of the automotive lighting component.

[0011] In addition to the features mentioned in the preceding paragraph, the lighting circuit according to one aspect of the invention may have one or more of the following additional features, considered individually or in any technically possible combination:

- the compensation circuit comprises a first resistor connected in series with a sensing circuit,
- the compensation circuit comprises a second resistor and with a negative temperature coefficient thermistor, the second resistor and the negative temperature coefficient thermistor being connected in parallel,
- the compensation circuit is configured to modify the intensity of the electric current driving the at least one light source of the plurality of light sources by modifying an equivalent resistance value based on the detected variation of the temperature of the at least one light source of the plurality of light sources,
- the equivalent resistance is based at least partially on a multiplication factor of the integrated circuit,
- the equivalent resistance is based at least partially on the detected variation of the temperature of the at least one light source of the plurality of light sources,
- the compensation circuit enables the integrated circuit to maintain a constant flux and to modify the intensity of the electric current driving the at least one light source of the plurality of light sources,

- when the sensing circuit comprises a positive temperature coefficient thermistor, the compensation circuit is adapted to modify the intensity of the electric current driving the at least one light source of the plurality of light sources.

[0012] A second aspect of the invention relates to a method for controlling a level of a luminous flux produced by at least one light source of a plurality of light sources comprising:

- Identifying, by a compensation circuit, a thermal drift curve of the level of a luminous flux produced by the at least one light source of the plurality of light sources for a range of variations of temperature of the at least one light source of the plurality of light sources, the thermal drift value being determined at a predetermined intensity of a drive current of an integrated circuit driving the at least one light source of the plurality of light sources,

- Identifying, by the compensation circuit, an electric curve of the level of the luminous flux produced by the at least one light source of the plurality of light sources for a range of the intensity of the drive current, the electric curve being determined at a predetermined temperature of the at least one light source of the plurality of light sources,

- Calculating, by the compensating circuit, a compensating curve of the intensity of the drive current to drive the at least one light source of the plurality of light sources for a range of the temperature of the at least one light source of the plurality of light sources by using the thermal drift and electric curves, the compensating curve defining, for each temperature of the temperature range, the intensity of the drive current needed to drive the at least one light source of the plurality of light sources in order to maintain the level of the luminous flux within a range of luminous flux levels,

- Calculating, by the compensating circuit, an equivalent resistance value for each temperature of the range of the temperatures of the at least one light source of the plurality of light sources, the equivalent resistance value modifying the drive current driving the at least one light source of the plurality of light sources according to the value of the temperature of the at least one light source of the plurality of light sources as defined by the compensating curve.

- Controlling, by the compensating circuit, the level of a luminous flux produced by at least one light source of a plurality of light sources.

[0013] The method according to the second aspect of the invention may also have one or more of the following characteristics, considered individually or according to any technically possible combinations thereof:

- after the identifying an electric signature curve and before the calculating a compensating curve, the method further comprises:
    - Calculating a modified temperature value for each temperature of the temperature range, the modified temperature value being calculated by:
        - Obtaining the temperature value at a pad of the at least one light source of the plurality of light sources; and
        - Applying correction factors to the obtained temperature value; and
        - Calculating the modified temperature value based on the applied correction factors, the modified temperature value corresponding to a junction temperature of the at least one light source of the plurality of light sources.

[0014] A third aspect of the invention relates to an automotive lighting device comprising a housing and a lighting circuit according to the invention.
[0015] A fourth aspect of the invention relates to a computer program comprising instructions for performing the method according to the invention.
[0016] A fifth aspect of the invention relates to a computer readable storage medium having recorded thereon the computer program according to the invention.

BRIEF DESCRIPTION OF THE FIGURES

[0017] Other characteristics and advantages of the invention will become clear from the description that is given thereof below, by way of indication and in no way limiting, with reference to the appended figures, among which:

Figure 1 shows an example of luminous fluxes produced by 3 LEDs for a range of a junction temperature comprised between -40 degrees Celsius (°C) and +70 °C and for various intensities of the current driving the LED.

Figure 2 is a synoptic scheme illustrating the steps of an example of the method 100 according to the invention.

Figure 3 shows an example of a compensation circuit having an architecture compatible with the invention.

Figure 4 shows values of luminous fluxes obtained for three different models of LEDs for a range of temperatures.

DETAILED DESCRIPTION

[0018] For greater clarity, identical or similar elements are marked by identical reference signs in all of the figures. Furthermore, the same variable appearing in different paragraphs has a unique name.

[0019] The present invention relates to a lighting circuit for an automotive lighting device. The lighting circuit comprises a plurality of light sources being configured to produce a level of a luminous flux. The lighting circuit also comprises an integrated circuit being configured to supply a driving current to bias the level of the luminous flux of at least one light source of the plurality of light sources. The lighting circuit also comprises a compensation circuit connected with the integrated circuit. The compensation circuit is configured to modify an intensity of the electric current driving the at least one light source of the plurality of light sources. A level of the modification of the electric current is dependent on a detected variation of temperature of the at least one light source of the plurality of light sources. The lighting circuit is exposed to temperature variations, for example between -40°C and +70°C. The light source of the automotive lighting component produces a luminous flux whose level is dependent on the value of the temperature of the lighting circuit. The level of the luminous flux is also dependent on the intensity of the electric current driving the light source. The compensation circuit modifies the intensity of the electric current driving the light source. The level of the modification of the electric current is dependent on the value of the temperature of the lighting circuit. The lighting circuit according to the invention makes it possible to obtain a constant luminous flux. By "constant luminous flux", it is meant a level of the luminous flux maintained within a range of luminous flux levels, for example the flux is maintained at a constant level with a range of variations of 15% and more preferably 5%. The constant luminous flux is obtained thanks to the specific features of the compensation circuit. Indeed, the compensation circuit modifies the intensity of electric current driving the light source to compensate the variations of the level of the luminous flux of the light source due to the variations of the value of the temperature of the lighting circuit. In other words, the level of modification of the current driving the light source is specifically adapted by the compensation circuit to compensate the modification of the level of the luminous flux induced by the temperature variations. The light source may be predetermined and the purpose of the invention, in this case, is to design an compensation circuit adapted to this predetermined light source.

[0020] Therefore, to obtain a stable luminous flux, the compensation circuit is designed to modify the intensity of a current following the temperature of the light source, with the goal of compensating the drift of the luminous flux produced by such temperature changes. As a first approximation, the relationship between the biasing current and the intensity of the light emitted by a LED can be considered linear (D. Peng and K. Liu, "Modeling Study of Red LED Spectral Characteristics", J. Phys.: Conf. Ser., 1746, 012003, 2021):

$$(1)\ \emptyset r = a \times I$$

[0021] With:

- *Ør* the relative luminous flux,
- *a* the proportionality constant, and
- *I* the intensity of the current driving the LED.

[0022] The proportionality constant is a parameter which is specific for each specific model of LED. Indeed, the relationship is a simplified model of the LED. Hence, the flux is supposed linear versus bias current of the component, and hence the relation between flux and current is also supposed linear.

[0023] In addition, the relative luminous flux *Ør* can be expressed as a function of the temperature (J. Yan, H. Liu, W. Zhao and Y. Su, "Temperature compensation for LED filament standard lamps" in Proc. SPIE 11189, Optical Metrology and Inspection for Industrial Applications VI, 111891N, 18 November 2019 when the bias current is constant) :

$$(2)\ \emptyset r = e^{\alpha(T_j - T_{j0})}$$

[0024] With:

- α a temperature coefficient of the LED,
- T_j the junction temperature of the LED, and
- T_{j0} the reference junction temperature, which is typically 25°C.

[0025] From these two equations (1) and (2), the drift of the luminous flux caused by changes in the internal temperature can be modelled as a thermal dependence of the biasing current:

$$(3)\ I_T = \frac{e^{\alpha(T_j - T_{j0})}}{a} = \frac{e^{-\alpha T_{j0}}}{a} \times e^{\alpha T_j} = ß \times e^{\alpha T_j}$$

[0026] With β a constant number representing the intensity of a fixed current.

[0027] Therefore, it is possible to compensate the thermal drift of the emitted light if the driving system is able to generate a bias current I_{bias} that follows a behavior opposite to the last equation, that is:

$$(4)\ I_{bias} = I_0 \times e^{-\alpha T_j}$$

[0028] With I_0 a constant factor which includes the thermal dependence of the Equation (3).

[0029] By using a compensation circuit to modify the current driving the light source, the volume of the lighting circuit is minimized. Furthermore, the compensation circuit, thanks to its small size, may be located close to the light source, therefore the variations of the temperature impacting the light source and the compensation circuit are similar. It is an advantage to ensure that the modification of the current driving the light source compensates the modification of the level of the luminous flux due to the variations of temperature. Furthermore, such compensation circuit may comprise only commercially available components such as one or more resistors and/or one or more thermistors.

[0030] The current value may be generated according to the Equation (1) with a commercial integrated driver (switching or linear system) such as an Elmos™ 522.8X or an Elmos™ 522.9X. Therefore, the compensation circuit, as the one presented in figure 3, needs to have a resistance R_S which is defined by:

$$(5)\ R_S = K \times \frac{V_{IR}}{I_0} \times e^{\alpha T_j}$$

[0031] With:

- K the current amplification factor of the compensation circuit, which is constant for a given compensation circuit,
- V_{IR} the reference voltage of the compensation circuit, and
- I_0 a constant factor which includes the thermal dependence of the equation (3).

[0032] This implies that a variable resistor whose resistance value depends exponentially on the temperature may be used in the compensation circuit. In an example, the compensation circuit of the present invention may comprise a first resistor, connected in series with a sensing circuit. In a preferred example, the compensation circuit of the present invention may comprise a first resistor, connected in series with a second resistor. The first resistor is also connected in series with a negative temperature coefficient thermistor, noted NTC in the present application. The second resistor and the NTC may be considered as the sensing circuit. The second resistor and the NTC are connected in parallel, and the NTC is placed close to a pad of the light source. By "close to", it is meant for example between 5 and 15 millimeters. This distance could be modified for a given application if needed. A thermal simulation could help also to find the optimal place for the component. Figure 3 shows an example of such compensation circuit with R1, the resistance of the first resistor, R2 the resistance of the second resistor and RNTC the resistance of the NTC. The compensation circuit of the figure 3 has therefore an equivalent resistance noted REQ.

[0033] Since α is always negative for a light source, an NTC may be an appropriate device to compensate the thermal drift of the luminous flux. Indeed, the nominal resistance value of an NTC decreases exponentially with temperature:

$$(6)\ R_{NTC} = R_0 \times e^{B\left(\frac{1}{T} - \frac{1}{T_0}\right)}.$$

[0034] With:

- R_{NTC} the resistance of the NTC at an ambient temperature T,
- R_0 the resistance of the NTC at an ambient temperature T_0, and
- B the constant of the NTC.

[0035] As it can be seen in Equation (6), the thermal dependence of an NTC is expressed in terms of the inverse of the temperature. To configure a resistance that varies with the temperature in a similar mode as the expressed in Equation (6), a compensation circuit such as the one of figure 3 may be used. The equivalent resistance R_{EQ} of this compensation circuit is calculated as:

$$(7)\ R_{EQ} = R_1 + R_{NTC} \parallel R_2 = R_1 + \frac{R_2 \times R_0 \times e^{B\left(\frac{1}{T} - \frac{1}{T_0}\right)}}{R_2 + R_0 \times e^{B\left(\frac{1}{T} - \frac{1}{T_0}\right)}}.$$

[0036] Furthermore, the internal junction temperature of the light source noted Tj is experimentally obtained by means of a common indirect measurement method (J. Bielecki, A. S. Jwania, F. El Khatib and T. Poorman, "Thermal Considerations for LED Components in an Automotive Lamp," in Twenty-Third Annual IEEE Semiconductor Thermal Measurement and Management Symposium, 2007, pp. 37-43). It consists in measuring the pad lead temperature Tp and extrapolating with a thermal resistance value R_{th}, expressed in Kelvin per Watt, provided by the light source manufacturer and the operating power P to find the junction temperature using the following relationship:

$$(8)\ T_j = T_P + R_{th} \times P$$

[0037] With :

- T_j the junction temperature of the light source,
- T_P the pad temperature of the light source,
- R_{th} the thermal resistance of the light source, and
- P the power value.

[0038] In the compensation circuit of the preferred example, the NTC is placed close to the pad of the light source. Hence, the ambient temperature T in Equation (6) corresponds to the pad temperature in Equation (7). In this way, Equation (7) can be expressed in terms of the junction temperature as:

$$(9)\ R_{EQ} = R_1 + R_{NTC} \parallel R_2 = R_1 + \frac{R_2 \times R_0 \times e^{B\left(\frac{1}{T_j - R_{th} \times P} - \frac{1}{T_0}\right)}}{R_2 + R_0 \times e^{B\left(\frac{1}{T_j - R_{th} \times P} - \frac{1}{T_0}\right)}}.$$

[0039] An appropriate selection of R_1, R_2, R_0 and B parameters can lead to a behavior of R_{EQ} very close to the resistance R_S in Equation (5) over a certain interval of temperature. By "very close", it is meant less than 10% of difference between the behavior of R_{EQ} and the behavior of the resistance R_S. Therefore, it is possible to make use of an integrated commercial driver for the generation of a current that varies with temperature in order to maintain a stable luminous flux through the introduction of a resistive network containing a thermistor as resistive shunt for the driver configuration.

[0040] Figure 4 shows values of luminous fluxes obtained for three different models of LEDs for a range of temperatures. For each diagram, Figure 4 shows the relative luminous compensated flux and non-compensated flux levels for a range of temperature. By "luminous compensated flux", it is meant that a compensation circuit according to the invention is used to compensate the thermal drift of the emitted light. By "luminous non-compensated flux", it is meant that nothing is implemented to compensate the thermal drift of the emitted light. Figure 4 shows also displays the bias current driving the LED for the luminous compensated flux example. Figure 4A, 4B and 4C respectively correspond to a first, second and third embodiments. As can be seen from the figure 4, the compensated luminous flux levels determined by the present invention can be maintained relatively stable over a large temperature range. Additionally, there are no steep variations in the flux levels over the temperature range.

[0041] The three embodiments have an architecture as described in Figure 3. These three embodiments may be used with a commercially available integrated current drive such as an an Elmos™ 522.82 or an Elmos™ 522.92. In the first implementation mode, the LED is a Dominant DWA MKG™ and the first resistor has a first resistance value R1 of 5 kiloohms, the second resistor has a second resistance value R2 of 15 kiloohms, the negative temperature coefficient thermistor has a third resistance value RNTC of 15 kiloohms / 3380 for a rated current of 50 milliamperes at 50 degrees Celsius. In this first embodiment, the variation of the compensated flux is around 4.2% versus 59.7% for a non-compensated flux.

[0042] In the second embodiment, the LED is a Dominant DWY MKG™ and the first resistor has a first resistance value R1 of 1,5 kiloohms, the second resistor has a second resistance value R2 of 40 kiloohms, the negative temperature coefficient thermistor has a third resistance value RNTC of 45 kiloohms / 3380 for a rated current of 50 milliamperes at 50 degrees Celsius. In this second embodiment, the variation of the compensated flux is around 13.1% versus 115% for a non-compensated flux.

[0043] In the third embodiment, the LED is a Nichia NFSW172AT™ and the first resistor has a first resistance value R1 of 11,5 kiloohms, the second resistor has a second resistance value R2 of 4,2 kiloohms, the negative temperature coefficient thermistor has a third resistance value RNTC of 10 kiloohms / 3380 for a rated current of 50 milliamperes at 50 degrees Celsius. In this third embodiment, the variation of the compensated flux is around 2.2% versus 8.2% for a non-compensated flux.

[0044] A second aspect of the invention concerns a method for controlling a level of a luminous flux produced by at least one light source of a plurality of light sources.

[0045] Figure 2 is a synoptic scheme illustrating the steps of an example of the method 100 according to the invention. The mandatory steps of the example of the method 100 are indicated by a rectangle with solid lines and the optional steps are indicated by a rectangle with dashed lines.

[0046] A first step 110 of the method 100 is to identify, by a compensation circuit, a thermal drift curve of the level of a luminous flux produced by the at least one light source of the plurality of light sources for a range of variations of temperature of the at least one light source of the plurality of light sources. As an example, the range of temperatures may be between -40 °C and +70 °C. The thermal drift signature curve must be determined at a predetermined intensity of the electric current driving at least one light source of the plurality of light sources.

[0047] A second step 120 of the method 100 is to identify, by the compensation circuit, an electric curve of the level of the luminous flux produced by the at least one light source of the plurality of light sources for a range of the intensity of the drive current. As an example, the range of intensities may be between 10 and 70 milliamperes. The electric signature curve must be determined at a predetermined temperature of the at least one light source of the plurality of light sources.

[0048] A third optional step 130 of the method 100 is to calculate a modified temperature value for each temperature of the temperature range. The modified temperature value is calculated by, first, obtaining the temperature value at a pad of the at least one light source of the plurality of light sources. Second, correction factors are applied to the obtained temperature value and third the modified temperature value based on the applied correction factors is calculated. The modified temperature value corresponds to a junction temperature of the at least one light source of the plurality of light sources.

[0049] A fourth step 140 of the method 100 is to calculate, by the compensating circuit, a compensating curve of the intensity of the electric current to drive the at least one light source of the plurality of light sources for a range of temperatures of the at least one light source of the plurality of light sources. The compensating curve is calculated for a range of the temperature of the automotive lighting component by using the thermal drift and electric signature curves by using the thermal drift and electric curves. The compensating curve defines, for each temperature of the temperature range, the intensity of the electric current needed to drive the at least one light source of the plurality of light sources in order to maintain the level of the luminous flux within a range of luminous flux levels.

[0050] A fifth step 150 of the method 100 is to calculate, by the compensating circuit, an equivalent resistance value for each temperature of the range of the temperatures of the at least one light source of the plurality of light sources. The equivalent resistance value modifies the drive current driving the at least one light source of the plurality of light sources according to the value of the temperature of the at least one light source of the plurality of light sources as defined by the compensating curve.

[0051] A sixth step 160 of the method 100 is to control, by the compensating circuit, the level of a luminous flux produced by at least one light source of a plurality of light sources. The level of the luminous flux output from the plurality of LEDs is maintained substantially stable by varying the drive current being supplied to the plurality of light sources. The drive current can be varied by the integrated circuit based on the equivalent resistance value provided by the compensation circuit. The appropriate equivalent resistance value is determined by the compensation circuit by utilizing the thermal model as described previous paragraphs.

Claims

1. A lighting circuit for an automotive lighting device, the lighting circuit comprising:

- a plurality of light sources being configured to produce a level of a luminous flux,
- an integrated circuit being configured to supply a driving current to bias the level of the luminous flux of at least one light source of the plurality of light sources, and
- a compensation circuit connected with the integrated circuit, the compensation circuit being configured to modify an intensity of the electric current driving the at least one light source of the plurality of light sources, a level of the modification of the electric current being dependent on a detected variation of temperature of the at least one light source of the plurality of light sources, and

wherein, based on the detected variation of the temperature of the at least one light source of the plurality of light sources, the level of the luminous flux is maintained within a range of luminous flux levels.

2. The Lighting circuit of claim 1 wherein the compensation circuit comprises a first resistor connected in series with a sensing circuit.

3. The Lighting circuit of claim 2 wherein the sensing circuit comprises a second resistor and with a negative temperature coefficient thermistor, the second resistor and the negative temperature coefficient thermistor being connected in parallel.

4. The Lighting circuit of claim 3 wherein the compensation circuit is placed close to a pad of the at least one of the plurality of light sources.

5. The lighting circuit according to any of the previous claims, wherein the compensation circuit is configured to modify the intensity of the electric current driving the at least one light source of the plurality of light sources by modifying an equivalent resistance value based on the detected variation of the temperature of the at least one light source of the plurality of light sources.

6. The Lighting circuit according to claim 5, wherein the equivalent resistance is based at least partially on a multiplication factor of the integrated circuit.

7. The Lighting circuit according to claim 5, wherein the equivalent resistance is based at least partially on the detected variation of the temperature of the at least one light source of the plurality of light sources.

8. The Lighting circuit according to any of the previous claims wherein the compensation circuit enables the integrated circuit to maintain a constant supply voltage and to modify the intensity of the electric current driving the at least one light source of the plurality of light sources.

9. The lighting circuit according to any of the previous claims wherein when the sensing circuit comprises a positive temperature coefficient thermistor, the compensation circuit is adapted to modify the intensity of the electric current driving the at least one light source of the plurality of light sources.

10. Automotive lighting device comprising a housing and a lighting circuit according to any of claims 1 to 9.

11. Method (100) for controlling a level of a luminous flux produced by at least one light source of a plurality of light sources comprising:

- Identifying (110), by a compensation circuit, a thermal drift curve of the level of a luminous flux produced by the at

least one light source of the plurality of light sources for a range of variations of temperature of the at least one light source of the plurality of light sources, the thermal drift value being determined at a predetermined intensity of a drive current of an integrated circuit driving the at least one light source of the plurality of light sources,
- Identifying (120), by the compensation circuit, an electric curve of the level of the luminous flux produced by the at least one light source of the plurality of light sources for a range of the intensity of the drive current, the electric curve being determined at a predetermined temperature of the at least one light source of the plurality of light sources,
- Calculating (140), by the compensating circuit, a compensating curve of the intensity of the drive current to drive the at least one light source of the plurality of light sources for a range of the temperature of the at least one light source of the plurality of light sources by using the thermal drift and electric curves, the compensating curve defining, for each temperature of the temperature range, the intensity of the drive current needed to drive the at least one light source of the plurality of light sources in order to maintain the level of the luminous flux within a range of luminous flux levels,
- Calculating (150), by the compensating circuit, an equivalent resistance value for each temperature of the range of the temperatures of the at least one light source of the plurality of light sources, the equivalent resistance value modifying the drive current driving the at least one light source of the plurality of light sources according to the value of the temperature of the at least one light source of the plurality of light sources as defined by the compensating curve.
- Controlling (160), by the compensating circuit, the level of a luminous flux produced by at least one light source of a plurality of light sources.

12. Method of the claim 11 wherein after the identifying (120) an electric signature curve and before the calculating (140) a compensating curve, the method further comprises:

- Calculating (130) a modified temperature value for each temperature of the temperature range, the modified temperature value being calculated by:

◦Obtaining the temperature value at a pad of the at least one light source of the plurality of light sources; and
◦Applying correction factors to the obtained temperature value; and
◦Calculating the modified temperature value based on the applied correction factors, the modified temperature value corresponding to a junction temperature of the at least one light source of the plurality of light sources.

13. A computer program comprising instructions for performing the method according to any one of the claims 11 to 12.

14. A computer readable storage medium having recorded thereon the computer program of claim 13.

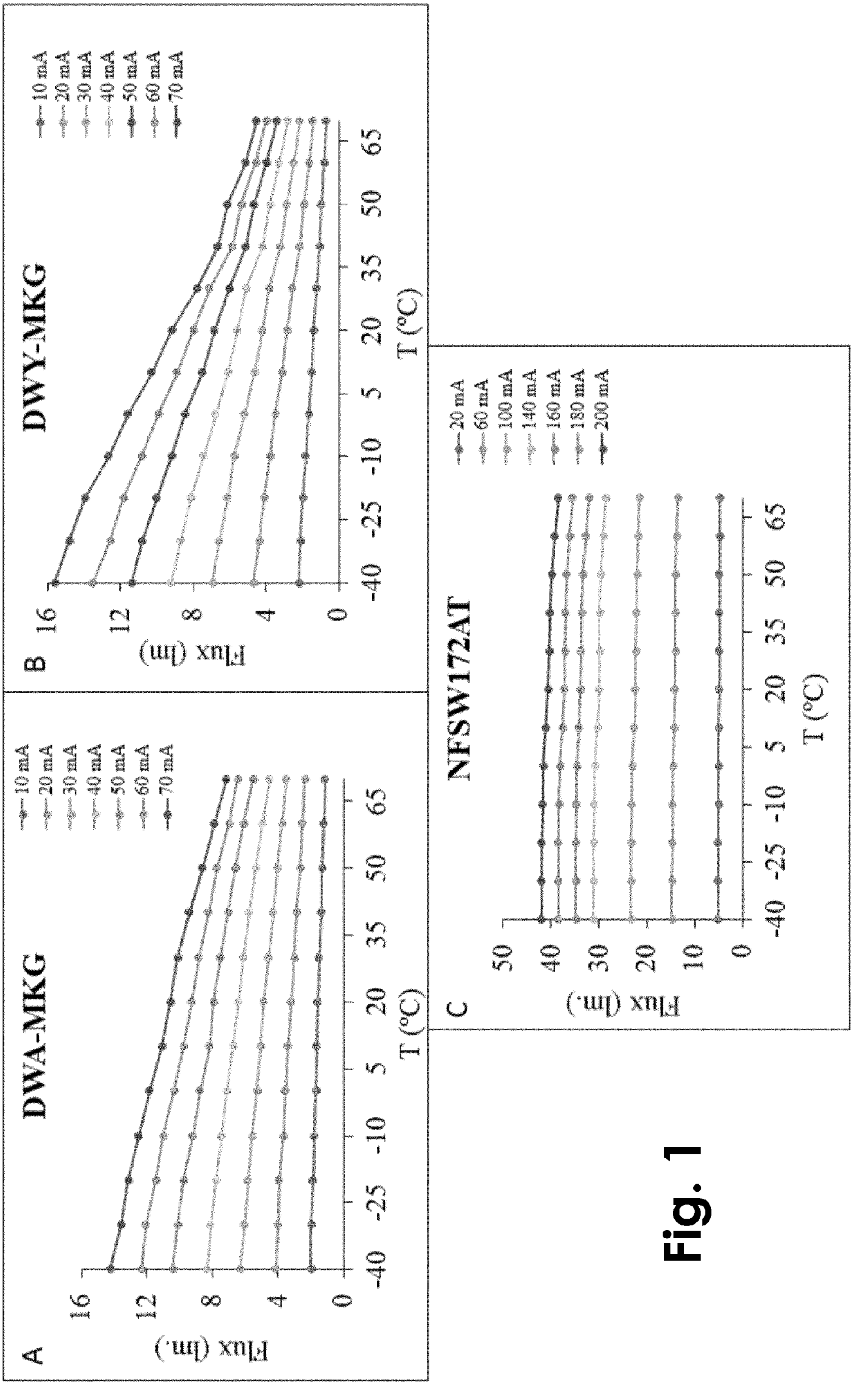
A
DWA-MKG
Flux (lm.)
T (ºC)
10 mA
20 mA
30 mA
40 mA
50 mA
60 mA
70 mA
B
DWY-MKG
Flux (lm)
T (ºC)
10 mA
20 mA
30 mA
40 mA
50 mA
60 mA
70 mA
C
NFSW172AT
Flux (lm.)
T (ºC)
20 mA
60 mA
100 mA
140 mA
160 mA
180 mA
200 mA

Fig. 1

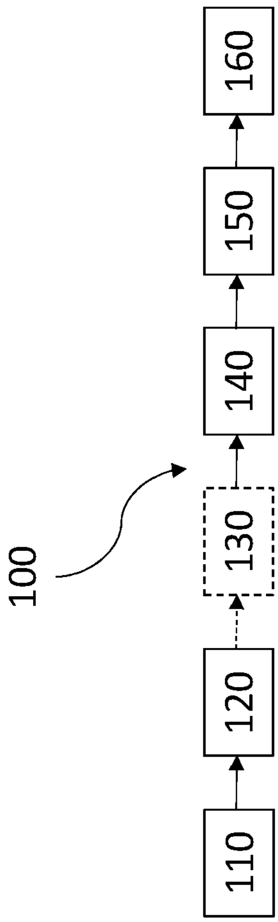

Fig. 2

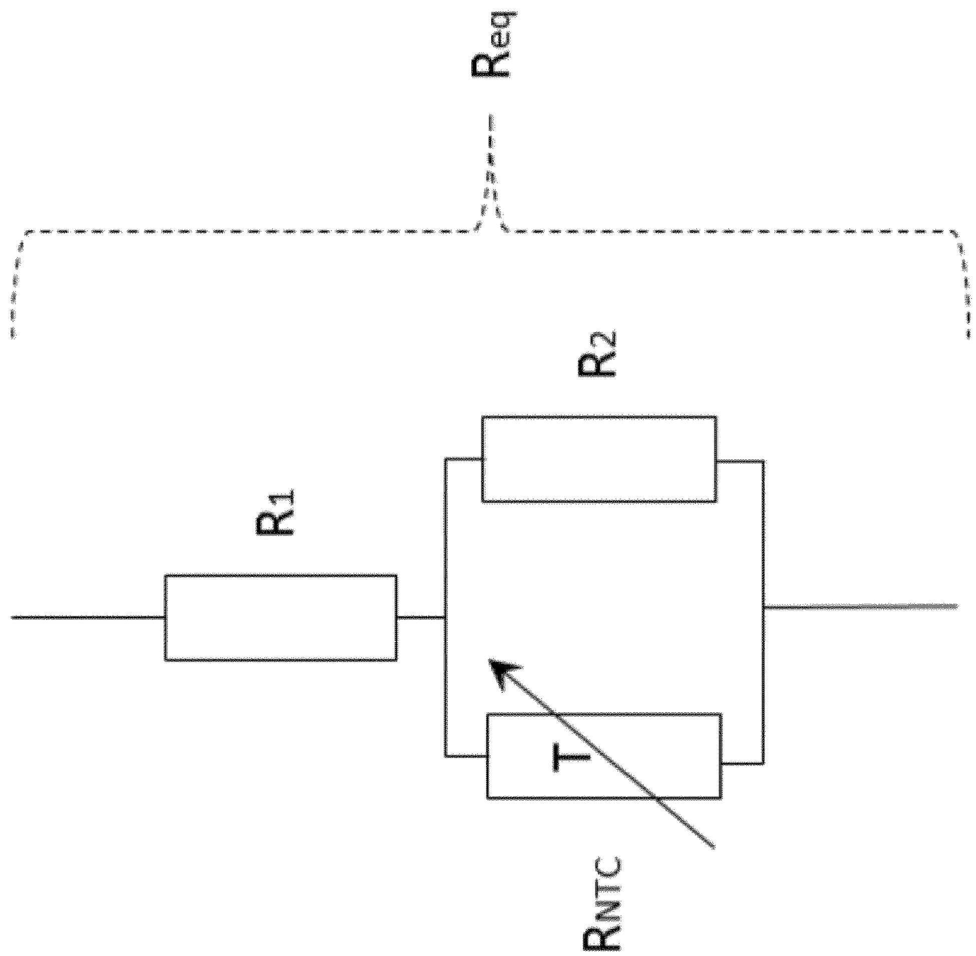

Fig. 3

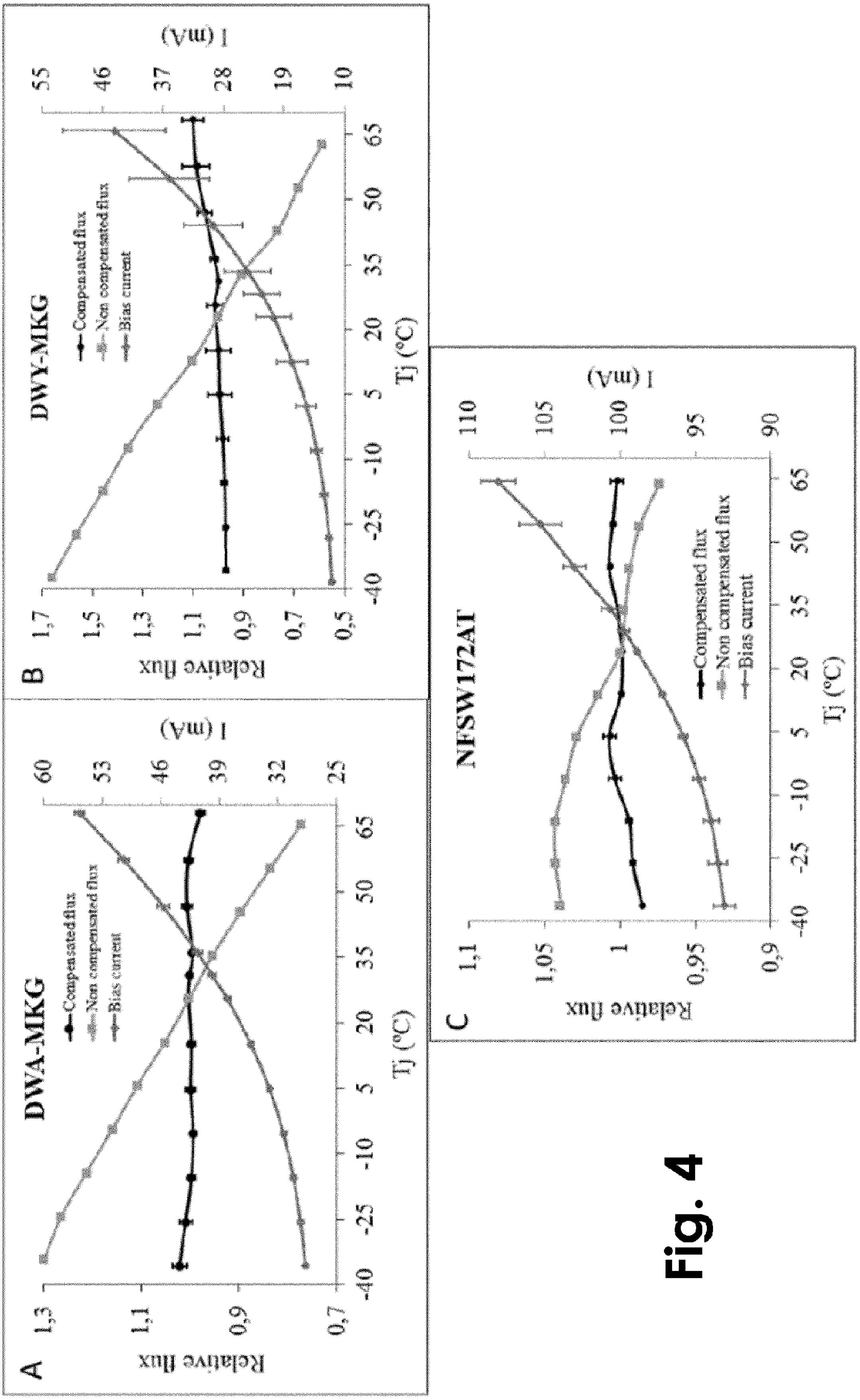
A
DWA-MKG
Compensated flux
Non compensated flux
Bias current
Relative flux
I (mA)
Tj (°C)
B
DWY-MKG
C
NFSW172AT

Fig. 4

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EUROPEAN SEARCH REPORT

Application Number
EP 23 38 2613

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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H05B
F21S

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	5 December 2023	Hernandez Serna, J

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