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(54) **A METHOD FOR ADJUSTING OPERATING CURRENT, A CURRENT SETTING ELEMENT AND A LED MODULE**

(57) A method and a current setting element are provided for adjusting operating current provided to a LED array by a LED driver. A setting current is provided at a current setting interface of the LED driver. The setting

current is adjusted as a function of time recorded by a timer. Adjustments in the setting current cause corresponding adjustments in the operating current.

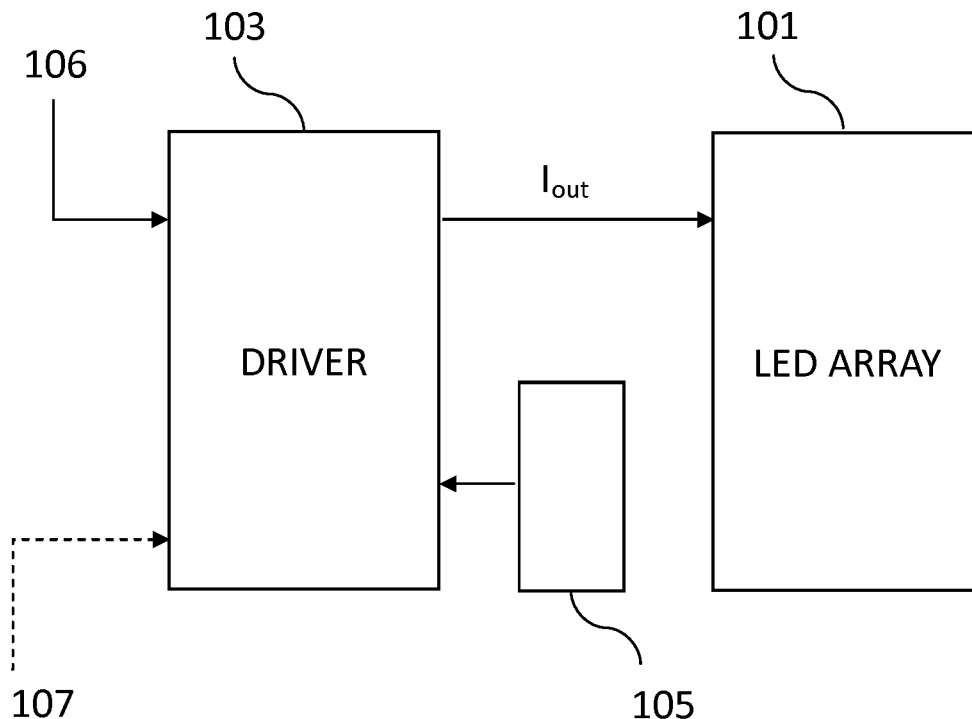


Figure 1

Description

FIELD OF THE INVENTION

[0001] The invention relates to control of operation of light sources. In particular, the invention relates to a method for adjusting operating current provided to a light source, a current setting element for adjusting the operating current and a LED module comprising a current setting element.

BACKGROUND OF THE INVENTION

[0002] Light emitting diodes (LEDs) are becoming more and more popular light source for illumination, replacing fluorescent and incandescent light sources. LEDs have several advantages over their traditional alternatives, such as long lifetime and high energy efficiency.

[0003] LEDs are often operated with a constant current power source. LED manufacturers indicate LED performance, such as lumen output indicative of light output, at certain nominal current(s). However, the light output of LEDs does not remain constant over the whole LED lifetime. Instead, as a LED ages, its light output is reduced. The reduction is dependent both on the operating time of the LED as well as on the operating temperature. Therefore, if LEDs are operated at a constant current, after certain time, the light output will no longer correspond to specification.

[0004] The light output reduction can be compensated by using a controllable LED driver that is programmed or controlled to increase the operating current over time. However, controllable LED drivers typically have a much larger (average) current range than is needed to compensate for the reduction in light output. Controllable LED drivers also have a control interface for receiving control commands. The unnecessary features, such as the large (average) current range and the control interface, increase the cost of the driver.

SUMMARY OF THE INVENTION

[0005] It is an object of the present invention to provide a simple and affordable way of adjusting the operating current provided to a LED array to compensate for the reduction in light output as the LED array ages.

[0006] The objects of the invention are reached by a method, a current setting element and a LED module as defined by the respective independent claims.

[0007] According to a first aspect of the invention a method for adjusting operating current provided to a LED array by a LED driver is provided. The method comprises providing a setting current at a current setting interface of a LED driver, and adjusting the setting current as a function of time recorded by a timer. The adjustment in the setting current cause corresponding adjustments in the operating current.

[0008] According to a second aspect of the invention a current setting element is provided. The current setting element comprises a first terminal and a second terminal for connection to a current setting interface of a LED driver. The current setting element further comprises a controllable current source on a current path from the first terminal to the second terminal. The current setting element further comprises a control unit comprising a timer. The control unit is arranged to control the controllable current source based on the timer to adjust the magnitude of the current between the first terminal and the second terminal.

[0009] According to a third aspect of the invention a LED module is provided. The LED module comprises a LED array and at least one operating current terminal connectable to a LED driver for provision of operating current for operating the LED array. The LED module further comprises a current setting element according to a second aspect of the invention.

[0010] The exemplifying embodiments of the invention presented in this patent application are not to be interpreted to pose limitations to the applicability of the appended claims. The verb "to comprise" and its derivatives are used in this patent application as an open limitation that does not exclude the existence of also unrecited features. The features described hereinafter are mutually freely combinable unless explicitly stated otherwise.

[0011] The novel features which are considered as characteristic of the invention are set forth in particular in the appended claims. The invention itself, however, both as to its construction and its method of operation, together with additional objects and advantages thereof, will be best understood from the following detailed description of specific embodiments when read in connection with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012]

Figure 1 schematically illustrates an exemplary arrangement for using a current setting element to set the operating current provided to a LED array by a LED driver.

Figure 2 schematically illustrates some components of an exemplary LED driver.

Figure 3 schematically illustrates an exemplary current setting interface of a LED driver.

Figure 4 schematically illustrates a some components of a current setting element according to an exemplary embodiment of the invention.

Figure 5 schematically illustrates a current setting element according to an exemplary embodiment of the invention.

Figure 6 schematically illustrates an exemplary arrangement according to the invention for using a current setting element to set the operating current to a LED array.

Figure 7 schematically illustrates some components of a LED module comprising a current setting element according to an exemplary embodiment invention.

Figure 8 schematically illustrates some components of a LED module comprising a current setting element according to an exemplary embodiment invention.

DETAILED DESCRIPTION

[0013] Figure 1 illustrates an exemplary arrangement for using a LED array for illumination purposes. The arrangement comprises a LED array 101 comprising at least one LED. Preferably, the LED array comprises several LEDs. The LEDs of a LED array 101 may be essentially identical. Alternatively, the LEDs may be white LEDs with different colour temperatures. For example, some of the LEDs may be "cold white" (colour temperature above 4600K) and the remaining LEDs may be "warm white" (colour temperature up to 3000K). The LEDs may also have other colour than white. The LED array 101 may further comprise optical components such as lenses. The LED array 101 may form a part of a LED module, which may comprise additional components, for example resistors or arrangements for protecting the LEDs. Instead of a single LED array 101, the arrangement may comprise two or more LED arrays 101 connected in series or in parallel, or some of the LED arrays 101 may be connected in series while other LED arrays 101 are connected in parallel.

[0014] The operating current I_{out} is provided to the LED array 101 by a LED driver 103. The operating current I_{out} provided by the LED driver 103 is preferably constant direct current. The LED driver 103 is connected to a power supply, preferably to an alternating current power network 106. The LED driver 103 may also comprise a control interface for receiving external control commands 107. The control interface may receive external control commands to turn on or off the lights, in other words, instructions for the LED driver 103 to either begin or end provision of operating current I_{out} to the LED array 101. The external control commands 107 may originate from a switch such as a wall switch. The external control commands 107 may originate from a sensor, for example a presence sensor or a light level sensor. The external control commands 107 may also originate from a lighting control network, such as a DALI network. In addition to instructions for turning the lights on or off, the control interface may receive other commands. Alternatively, the provision of operating current I_{out} to the LED array 101 may be controlled by the power supplied to the LED driver

103. In other words, in order to stop the provision of operating current I_{out} to the LED array 101, power supply to the LED driver 103 is stopped.

[0015] Different LED arrays require different operating currents for optimal performance. One way to set the operating current I_{out} the LED driver 103 provides to the LED array 101 is to provide the LED driver 103 with a current setting interface. The operating current I_{out} is then set by connecting a current setting element 105 to the current setting interface.

[0016] An exemplary LED driver 203 is schematically illustrated in Figure 2. Input power for the LED driver 203 is obtained from an alternating current network 206. The alternating current is rectified using a rectifying bridge 215. The rectified alternating current is then converted by a power converter portion 216 into direct current, or operating current I_{out} , suitable for operating a LED array. The power converter portion 216 may comprise at least one switched mode power converter. For example, the power converter portion may comprise a first power converter stage for converting the rectified AC into a constant intermediate circuit voltage and a second power converter stage for converting the intermediate circuit voltage into constant direct current. The power converter portion 216 is controlled by a control portion 214. The control portion 214 also processes possible external control commands 207 and the control portion 214 controls the power converter portion 216 according to the external control commands 207. Current setting interface 211 receives current setting information 212 and provides a signal 213 indicative of requested operating current I_{out} to the control portion 214.

[0017] An exemplary current setting interface 311 is schematically illustrated in Figure 3. The interface comprises a constant voltage source 321. The interface also comprises a first connection terminal TC1 and a second connection terminal TC2 for connecting a current setting element. The first connection terminal TC1 is coupled to a first terminal of the constant voltage source 321 and the second connection terminal TC2 is coupled to a second terminal of the constant voltage source 321. Thus, a constant potential difference V is provided between the first and second connection terminals TC1 and TC2. The second connection terminal TC2 may additionally be connected to LED driver ground. When a current setting element is connected to the first connection terminal TC1 and the second connection terminal TC2, the current setting element closes the electric circuit, thus enabling current flow in the current setting circuit. The magnitude of the current depends on the properties of the current setting element. For example, the current setting element may be a resistor with resistance R . With the constant voltage source 321 providing a constant potential difference V , the current in the current setting circuit will be equal to V/R .

[0018] The magnitude of the current in the current setting circuit, in other words the setting current I_{set} , is determined at node N1 located between the first terminal

of the constant voltage source V and the first connection terminal TC1. The measured signal indicative of magnitude of setting current I_{set} is evaluated by current detection portion 322. The current detection portion 322 outputs a signal 313 indicative of the requested operating current based on the evaluation of the measured magnitude of setting current I_{set} . The signal 313 indicative of the requested operating current is received by control portion 214 of the LED driver. Based on the signal 313, the control portion 214 controls the power converter portion 216 to provide output current I_{out} corresponding to the requested current level. In this manner, the setting current I_{set} sets the magnitude of the operating current I_{out} provided to the LED array.

[0019] Preferably, the operating current I_{out} is directly proportional to the setting current I_{set} . In other words, there is a constant parameter C that relates the operating current to the setting current, $I_{out} = C \cdot I_{set}$. Alternatively, in addition to being directly proportional, a constant offset B may be applied: $I_{out} = C \cdot I_{set} + B$. The proportional relationship between the setting current I_{set} and operating current I_{out} may only be valid when the setting current I_{set} is within a predetermined range. For example, if the setting current I_{set} is larger than a predetermined upper limit, $I_{set,max}$, the corresponding operating current I_{out} may be equal to a predetermined maximum output current $I_{out,max}$. On the other hand, the operating current I_{out} provided to the LED array 101 will always be positive or zero, even if I_{set} would correspond to a negative operating current. There may be a predetermined minimum operating current $I_{out,min}$, corresponding to a minimum setting current $I_{set,min}$. The minimum operating current $I_{out,min}$ can be selected to be zero, or the minimum operating current $I_{out,min}$ may have a predetermined value greater than zero. Should the setting current I_{set} correspond to an operating current lower than the minimum operating current $I_{out,min}$, the driver can be programmed either to provide the minimum operating current $I_{out,min}$ or to not provide any operating current I_{out} . When no setting current I_{set} is flowing, for example when no current setting element 105 is connected to the current setting interface, no output current I_{out} will be provided.

[0020] When the driver is in stand-by state, in other words if the lights have been switched off using an external switch or a separate control interface, and thus no operating current I_{out} is required or wanted for operating the LED array 101, the constant voltage source 321 of the current setting interface 311 can be switched off. When the constant voltage source 321 is switched off and hence not providing a potential difference V in the current setting circuit, no current will flow in the current setting circuit. In other words, in this case, there is no setting current I_{set} when the LED array 101 is not providing light.

[0021] By using a resistor with a constant resistant value R , the setting current I_{set} will remain constant and thus a constant operating current I_{out} will be provided to the LED array 101. Instead of a resistor, a current regulator

can be used to ensure a constant setting current I_{set} and therefore also a constant operating current I_{out} .

[0022] However, the light output of a LED is reduced as the LED ages. For example, after 50,000 hours of use, the light output of a LED may be less than 80% of the initial light output. Therefore, when the operating current I_{out} provided to a LED array 101 is kept constant, over time the LED array 101 gives out less and less light. In applications where providing constant light output is essential, this reduction in light output needs to be compensated for. This can be accomplished by increasing the operating current I_{out} provided to the LED array over time.

[0023] According to the current invention, increasing the operating current to compensate for reduction in light output can be accomplished by using a timer. In a method according to the invention, the setting current I_{set} is adjusted based on time recorded by the timer. Adjustments in the setting current I_{set} cause corresponding adjustments in the operating current I_{out} , according to the operation principles of the current setting interface 104.

[0024] Preferably, the timer records duration of time when setting current I_{set} is provided at the current setting interface 211, 311 of the LED driver 103, 203. Operating current I_{out} is only provided to the LED array 101 when setting current I_{set} is provided at the current setting interface 211, 311, and therefore the duration of time when setting current I_{set} is provided at the current setting interface 211, 311 is a suitable estimator for the aging of the LEDs of the LED array 101.

[0025] Advantageously, the provision of constant voltage V by the constant voltage source 321 of the current setting interface 211, 311 is stopped when the LED driver 103, 203 is in standby state. The LED driver 103, 203 may enter into standby state when it receives a command to turn off the lights, or, in other words, receives a command to stop providing operating current I_{out} to the LED array 101. If the provision of constant voltage by the constant voltage source 321 is stopped when the LED driver 103, 203 is in standby state, the LED driver enables provision of setting current I_{set} only when the LED driver 103, 203 is providing operating current I_{out} to the LED array 101. Therefore, in this case, the duration of time when setting current I_{set} is provided at the current setting interface 211, 311 is an accurate estimate of the aging of the LEDs of the LED array 101.

[0026] Therefore, by adjusting the setting current I_{set} as a function of time recorded by a timer recording the duration of time when setting current I_{set} is provided at the current setting interface 104 of a LED driver 103, 203, the decrease in light output of LEDs of a LED array 101 due to aging can be compensated for.

[0027] The timer can be reset or replaced when the LED array 101 is replaced. That way, the time recorded by the timer after the replacement of the LED array will correspond to the aging of the LEDs 102 of the replacement LED array 101.

[0028] A current setting element according to the in-

vention is depicted in Figure 4. The current setting element 405 comprises two terminals, a first terminal T1 for connecting to the first connection terminal TC1 of the current setting interface 211, 311 of the LED driver 103, 203 and a second terminal T2 for connecting to the second connection terminal TC2 of the current setting interface 211, 311 of the LED driver 103, 203. A controllable current source 431 is coupled between the first terminal T1 and the second terminal T2. In other words, the controllable current source is on a current path from the first terminal T1 to the second terminal T2.

[0029] The current setting element 405 further comprises a control unit 432 for controlling the controllable current source 431. The control unit 432 comprises at least a timer TMR and control output I_{ctrl} . The control unit 432 is arranged to control the controllable current source 431 based on the timer TMR. The control unit 432 may be a microcontroller. The control unit 432 further comprises a memory MEM.

[0030] The control unit 432 advantageously draws operating power from the current setting circuit. The timer TMR can only record time when the control unit 432 is powered. If the control unit 432 draws operating power from the current setting circuit, the control unit 432 is only powered when setting current I_{set} is being provided. Hence timer TMR only records time when setting current I_{set} is being provided. If provision of the setting current I_{set} is only enabled by the LED driver 103, 203 when the LED driver 103, 203 is providing operating current Iout to the LED array 101, the timer TMR records time corresponding to the operating time of the LED array 101. Therefore, the time recorder by timer TMR will correspond to the operating time of the LED array 101.

[0031] In order for the control unit 432 to draw operating from the current setting circuit, the power supply pin Vcc of the control unit 432 is preferably coupled to the first terminal T1 and the ground pin GND of the control unit is preferably coupled to the second terminal T2.

[0032] When the operating power used by the control unit 432 is drawn from the current setting circuit, it will contribute to the total current in the current in the current setting circuit. Therefore, in order to accurately provide the setting current I_{set} , and, consequently, accurately set the operating current Iout, the current taken by the control unit 432 needs to be taken into account when controlling the controllable current source 431. Advantageously, setting current I_{set} in the current setting circuit is measured and the measured signal is led to current measurement pin I_{MES} of the control unit 432. Advantageously, the current measurement is performed in the current setting element 405 at a point close to either the first terminal T1 or the second terminal T2 such that the circuit does not have any branches between the measurement point and the first terminal T1 or the second terminal T2. Alternatively, the current can be measured with two or more measurements, for example one measurement for measuring the current in a circuit branch comprising the controllable current source 431 and another measurement

in a circuit branch comprising the control unit 432, when the controllable current source 431 and the control unit 432 are connected in parallel. The two or more measurements can then be summed to obtain the setting current I_{set} in the current setting circuit. According to another embodiment, if control of the controllable current source 431 is assumed to be accurate, it may be sufficient to only measure the current taken by the control unit 432. Alternatively, the control unit 432 may be configured to detect or estimate the amount of current it draws, and it may be sufficient to only measure the current through the controllable current source 431.

[0033] The control unit 432 controls the controllable current source 431 to provide a setting current I_{set} in the current setting circuit. If the control unit 432 receives current measurement information from the current setting circuit, the information is used to accurately control the setting current I_{set} to its target value. Initial value of the setting current I_{set} may be preprogrammed in the control unit 432. Alternatively, the initial value of the setting current I_{set} may be set when the current setting element 405 is connected to the LED driver 103, 203. According to a third alternative, the initial value of the setting current I_{set} may be adjusted or changed even during operation. For adjusting or changing the initial value of the setting current I_{set} , a simple control interface may be provided on the current setting element 405. The simple control interface may comprise, for example, a switch or a set of switches, such as dip switches or a rotatable switch; a sensor, such as a light sensor for receiving control commands in the form of light; connection terminals for connecting an element, such as a resistor, that defines the initial value of the setting current I_{set} ; or a wireless receiver. In addition to the initial value of the setting current I_{set} , also other parameter values of the control unit 432 may be adjustable via the control interface.

[0034] The timer TMR records time when the control unit 432 is receiving operating power, in other words time when setting current I_{set} is flowing in the current setting circuit. If the LED driver 103, 203 is arranged to stop provision of constant voltage V by the constant voltage source 321 when the LED driver 103, 203 is not providing operating power to the LED array 101, or, in other words, if LED driver 103, 203 enables provision of setting current I_{set} only when the LED driver is providing operating current Iout to the LED array 101, the control unit 432 is not receiving operating power and hence the timer TMR is not recording time when the LED driver 103, 203 is not providing operating current Iout.

[0035] When the current setting element 405 is first connected to the LED driver 103, 203 and the constant voltage source 321 of the LED driver 103, 203 is providing constant voltage V for the current setting circuit, the control unit 432 controls controllable current source 431 to provide setting current I_{set} equal to the initial value of the setting current I_{set} . Over time, as the timer TMR count increases, the control unit 432 controls the controllable current source 431 such that the setting current I_{set} is

increased.

[0036] Information regarding the light output reduction of a LED array is stored in the control unit 432. The information may either be expressed in terms of reduction in light output, or, preferably, in terms of operating current required to provide constant light output. Thus, in the memory MEM of the control unit 432 may be stored, either as a function or as a table, information relating the operating current I_{out} required to provide constant light output and the operating time of a LED. Alternatively, in the memory MEM of the control unit 432 may be stored, either as a function or as a table, information relating the light output and the operating time of a LED. In the latter case, additional information may be stored in the memory MEM of the control unit 432 providing instructions on how the reduced light output is compensated by increasing the operating current I_{out} . The information regarding the light output reduction of a LED array is preferably preprogrammed in the memory of the control unit 432. However, the information can be arranged to be changeable using the simple control interface used for changing the initial value of the setting current I_{set} .

[0037] The control unit 432 controls the controllable current source 431 based on the information regarding light output reduction of a LED array stored in the memory MEM of the control unit 432, such that the setting current I_{set} is increased in response to light output reduction according to the time recorded by timer TMR.

[0038] According to a first example embodiment, the setting current I_{set} is continuously adjusted such that the operating current I_{out} provided to the LED array 101 provides essentially constant light output at all times. Continuous adjustment is especially practical when the information regarding the light output reduction of a LED array is stored as a function, which can be used to calculate the required corrective actions for each moment in time. If the information regarding light output reduction of a LED array is stored as a table, interpolation between tabulated values may be needed to enable continuous adjustments. An advantage of continuous adjustment is that the light output of the LED array 101 is essentially constant over the full operating time because increased operating current I_{out} compensates for the reduction of LED light output due to aging. However, if the information regarding the light output reduction of a LED array stored in the memory MEM of the control unit 432 is not accurate or requires significant interpolation, it may turn out that despite continuous adjustments, the light output of the LED array 101 varies slightly. Also, adjustment of the setting current I_{set} affects the operating current I_{out} with some delay, introducing some time-lag between the adjustment of the setting current I_{set} and the corresponding change in the operating current I_{out} .

[0039] Alternatively, the setting current I_{set} is adjusted in discrete steps and the setting current I_{set} is kept constant between the steps. The required adjustment of the setting current I_{set} or the required value of the setting current I_{set} is obtained using the information regarding

reduction of light output of a LED array stored in the memory MEM of the control unit 432, either by calculating using a stored function, looking up from a stored table, or interpolating from a stored table.

[0040] According to a second example embodiment, the setting current I_{set} is adjusted in discrete steps after a fixed operating time recorded by the timer TMR of the control unit 432. For example, the setting current I_{set} , and hence also the operating current I_{out} , may be adjusted after each 5000 operating hours.

[0041] According to a third example embodiment, the setting current I_{set} is adjusted in discrete steps when the estimated reduction in light output of the LED array 101 reaches a preset limit, for example when the light output of the LED array 101 is estimated to have reduced by 2%. The preset limit may be smaller than 2%, for example 0.1 %, 0.5% or 1%. The preset limit may also be larger than 2%, for example 5% or even 10%. The preset limit may be set in accordance with the required accuracy of the light output of the LED array 101.

[0042] According to a fourth example embodiment, the setting current I_{set} is adjusted in discrete steps when the required increase in operating current I_{out} reaches a predetermined level. The predetermined level of required increase in operating current I_{out} may be set based on the accuracy of providing operating current I_{out} . For example, if the driver 103, 203 can provide operating current I_{out} to the LED array 101 with an accuracy of 10 mA, the setting current I_{set} may only be adjusted when the adjustments results in a change in operating current I_{out} of 10 mA, or more than 10mA. Alternatively, the current setting interface 211 may be sensitive only to adjustments of setting current I_{set} greater than an internal limit, and therefore, setting current I_{set} is adjusted only in increments equal to or larger than the internal limit.

[0043] According to fifth example embodiment, discrete steps correspond to each value tabulated in a table comprising the information regarding light output reduction of a LED array. Thus, any adjustment pattern for adjusting the setting current I_{set} can be created according to what is needed or seen practical.

[0044] The information regarding light output reduction of a LED array stored in the memory MEM of the control unit 432 can be specific to the LED array 101, or the information regarding light output of a LED array stored in the memory MEM of the control unit 432 can be generic information that represents information regarding a typical LED array, or a set of LED arrays with approximately similar properties in some regard.

[0045] The controllable current source 431 is preferably a transistor operated in linear region. An exemplary embodiment is shown in Figure 5. The control unit 532 is similar to the control unit 432 described in detail in connection with Figure 5. Also the first terminal T1 and the second terminal T2 in Figure 5 correspond to the first terminal T1 and the second terminal T2 of Figure 4. The controllable current source 531 in Figure 5 is a transistor. In the example of Figure 5, the transistor 531 is a npn

BJT, but a pnp BJT could also be used, or a FET. The collector of the transistor 531 is coupled to the first terminal T1 of the current setting element 505. The emitter of the transistor 531 is coupled to the second terminal T2 of the current setting element. The control pin I_{ctrl} of the control unit 532 is connected to the base of the transistor 531. In linear region, the current from the collector to the emitter is approximately directly proportional to the base-emitter current, controlled by the control pin I_{ctrl} . Therefore, by controlling the base-emitter current, the control unit 532 can control the current through the controllable current source 531 and hence set the setting current I_{set} to a value corresponding to the required operating current I_{out} . When the control unit also obtains feedback information in the form of setting current I_{set} measurement to current measurement pin I_{MES} of the control unit 532, the setting current I_{set} can be accurately controlled to the desired value.

[0046] The setting current I_{set} needs to be controlled to take values in a range from the initial value of setting current $I_{set,0}$ to a final value of setting current $I_{set,f}$. The initial value of setting current $I_{set,0}$ preferably corresponds to the nominal current of LED array 101, indicated by the manufacturer of the LED array 101. The final value of setting current $I_{set,f}$ corresponds to the output current required to produce an equivalent amount of light output by a LED array 101 at the end of its lifetime as was produced at initial value of setting current $I_{set,0}$ when the LED array 101 was first taken to use.

[0047] The current setting circuit may comprise also components not shown in preceding Figures. For example, one or more resistors can be connected in series with the controllable current source 431.

[0048] According to an embodiment of the invention, the current setting element 405, 505 is provided as an independent device as shown in Figure 1. When the current setting element 405, 505 is provided as an independent device, functionalities provided by the current setting element are all related to setting the value of setting current I_{set} . When the current setting element 405, 505 is provided as an independent device, the current setting element 405, 505 advantageously comprises a simple control interface as discussed hereinbefore. In addition to, or instead of, changing the initial value of setting current I_{set} or information related to reduction of light output of a LED array, the simple control interface can be used at least for resetting the timer TMR of the control unit 432, 532 upon replacement of the LED array 101 to which the LED driver 103, 203 provides operating current I_{out} . Additionally, the simple control interface can be used for selecting the type of LED array 101 for which operating current I_{out} is to be provided by the LED driver 103, 203 to which the current setting element 405, 505 is connected or is to be connected. The selection of type of LED array 101 may influence the selection of initial value of setting current I_{set} and the information related to the reduction in light output of a LED array, in case such values and information is stored in the memory MEM of the con-

trol unit 432, 532 for at least two types of LED arrays. The advantage of having the current setting element 405, 505 as an independent device is that the same current setting element 405, 505 can be used together with a variety of LED arrays 101. A current setting element as an independent device can be also freely positioned when connecting it to the current setting interface 211 of a LED driver 103, 203.

[0049] Preferably, the current setting element is provided as part of a LED module, as shown in Figure 6. The LED driver 603 is similar to the LED driver 103, 203 of Figure 1 and Figure 2. The LED driver 603 provides operating current I_{out} to a LED module 651. The LED module 651 comprises a LED array 601 similar to LED array 101 of Figure 1, and a current setting element 605. The advantage of providing the current setting element 605 as a part of a LED module 651 is that the type of LED array to which operating current I_{out} will be provided in accordance with the setting current I_{set} set by the current setting element 605 is known. The current setting element 605 is replaced together with the entire LED module 651, so there is no need to reset the timer of the current setting element 605 or to replace a separate current setting element.

[0050] An exemplary LED module 751 comprising a current setting element 705 is illustrated in Figure 7. The current setting element 705 is similar to current setting element 405, 505 discussed earlier, the only difference is that the current setting element 705 is provided as a part of a LED module 751. The current setting element 705 comprises a control unit 732, similar to the control unit 432, 532 of current setting element 405, 505 of Figures 4 and 5, respectively. The controllable current source 731 of current setting element 705 has the same properties as controllable current source 431 of Figure 4, and can be, for example, a transistor. The LED module 751 also comprises a LED array 703 comprising one or more LED light sources.

[0051] The operating current I_{out} for the LED array is provided by connecting operating current terminal T0 to an output current terminal of a LED driver 603. The operating current terminal T0 is coupled to the anode of the LED array 701. The cathode of the LED array 701 is coupled to the ground terminal of the LED driver 603. The first terminal T1 is coupled to the first connection terminal TC1 of the current setting interface 311 of the LED driver 603, and the second terminal T2 is coupled to the second connection terminal TC2 of the current setting interface 311. Because the second connection terminal TC2 is preferably connected to the LED driver 603 ground, it provides a connection to the LED driver 603 ground. Therefore, the cathode of the LED array 701 may be connected to the LED 603 driver ground by creating a connection in the LED module from the cathode of the LED array 701 to the second terminal T2. This way, only three connections are needed between the LED module 651, 751 and the LED driver 603.

[0052] In addition to operating time, also operating

temperature affects the aging of LED light sources. Therefore, the temperature of the LED array is preferably monitored and the setting current I_{set} is adjusted based on the temperature monitoring. Figure 8 provides an exemplary arrangement in this regard. Figure 8 shows a LED module 851 comprising a current setting element 805 and a LED array 801. The current setting unit comprises a controllable current source 831 and a control unit 832. The LED module 851 is connected to a LED driver 103, 203, 603 using three terminals: operating current terminal T0, the first terminal T1 and the second terminal T2. The LED module 851 is otherwise identical LED module 751, except for a temperature sensor 861 arranged in the vicinity of the LED array 801 and a temperature measurement pin T_{MES} in the control unit 832. The temperature of the LED array 801 is monitored using the temperature sensor 861 and the information is provided to the control unit 832. The control unit 832 may store some of the information received from the temperature sensor 861 in memory MEM of the control unit 832. The setting current I_{set} is adjusted based on the information provided by the temperature sensor and information saved in the memory MEM of the control unit 832. For example, if the LED array 801 is operated at an elevated temperature for a prolonged period of time, the setting current I_{set} may need be increased more than it would need to be increased based on operating time alone in order to obtain a constant light output from the LED array 801. The information related to reduction of light output of a LED array stored in the memory MEM of the control unit 832 may also comprise information related to the operating temperature or to the operating temperature history of the LED array.

[0053] The temperature of the LED array 101 may also be monitored even when the LED array 101 and the current setting element 405, 505 are not part of a common LED module. In such a case, the current setting element 405, 505 comprises an input for the temperature information, and a temperature sensor is arranged in the vicinity of the LED array 101.

[0054] According to another embodiment, dependency on temperature can be achieved by allowing the temperature measurement to affect the rate at which a timer advances. For example, the advancing rate of the timer may be directly proportional (not necessarily in strictly mathematical sense, but directly proportional in the sense that if one increases/decreases, also the other increases/decreases) to the measured temperature. According to another embodiment there may be one or more temperature thresholds, so that if the measured temperature is above a threshold, the timer is advanced at a higher rate than if the measured temperature was below the threshold.

[0055] According to another embodiment, a light sensor may be arranged to measure the light output of the LED array 101. The light sensor output may be used to control the controllable current source 431 of the current setting element 405.

[0056] The operating current lout provided to the LED array 101 by the LED driver 103 is constant direct current. The invention can also be used in connection with controllable LED drivers 103, which allow dimming of the LED array 101. In such a case, at full power, the operating current lout provided to the LED array 101 corresponds to the current set by the setting current I_{set} . If a dimmed light level is requested, for example by an external control signal 107, the dimming is preferably performed using pulse-width modulation. Thus, even when the LED array 101 is operated at a dimmed state, the operating current lout provided to it is of the magnitude set by the setting current I_{set} , and the light level is set by providing operating current lout at a duty cycle corresponding to the requested, dimmed light level.

[0057] Changes and variations to the described embodiments of the invention are possible. For example, in the case where the current setting element is provided as a part of a LED module and where the LED module also comprises other processor-controlled functions, the processor responsible for said other processor-controlled functions may be the same as that previously explained as operating within the current setting element. Similarly if the current setting element is provided as a part of some other structural element than LED module, and said other structural element contains a processor, the processing resources can be separated or combined into actual processor devices as necessary.

Claims

1. A method for adjusting operating current provided to a LED array by a LED driver, wherein
 - a setting current is provided at a current setting interface of the LED driver,
 - the setting current is adjusted as a function of time recorded by a timer, and
 - adjustments in the setting current cause corresponding adjustments in the operating current.
2. A method according to claim 1 wherein the timer records duration of time when setting current is provided at the control interface of the LED driver.
3. A method according to claim 2, wherein the LED driver enables provision of setting current only when the LED driver is providing operating current to the LED array.
4. A method according to any of the preceding claims, wherein the timer is reset or replaced when the LED array is replaced.
5. A method according to claim any of the preceding claims, wherein temperature of the LED array is

monitored and the setting current is adjusted based on temperature monitoring.

6. A current setting element, comprising
 - a first terminal and a second terminal for connection to a current setting interface of a LED driver,
 - a controllable current source on a current path from the first terminal to the second terminal, and
 - a control unit comprising a timer, wherein

the control unit is arranged to control the controllable current source based on the timer to adjust the magnitude of the current between the first terminal and the second terminal.
7. A current setting element according to claim 6, wherein the timer is arranged to record the time when current is flowing between the first terminal and the second terminal.
8. A current setting element according to claim 6 or 7, wherein the controllable current source is a transistor.
9. A current setting element according to any of claims 6-8, wherein the current setting element also comprises a temperature sensor or an interface for an external temperature sensor and the control unit is arranged to control the controllable current source based on combination of timer information and the temperature history.
10. A current setting element according to any of claims 6-9, wherein the current setting element comprises a current measurement arrangement for measuring the current from the first terminal to the second terminal.
11. A LED module comprising
 - a LED array,
 - at least one operating current terminal connectable to a LED driver for provision of operating current for operating the LED array, and
 - a current setting element according to any of claims 6-10.
12. A LED module according to claim 11, also comprising a temperature sensor for measuring the temperature of the LED module.

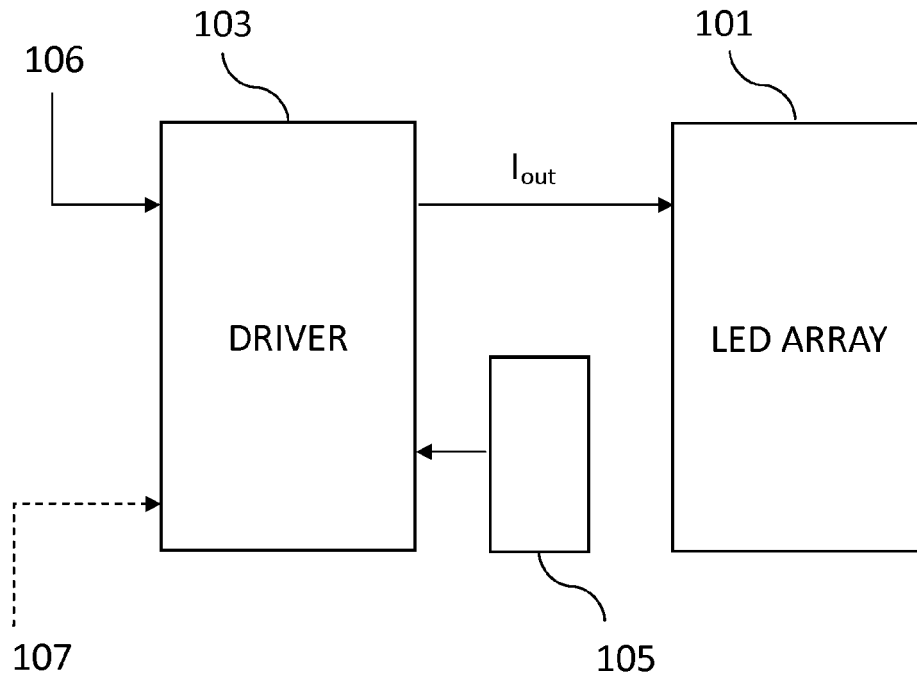


Figure 1

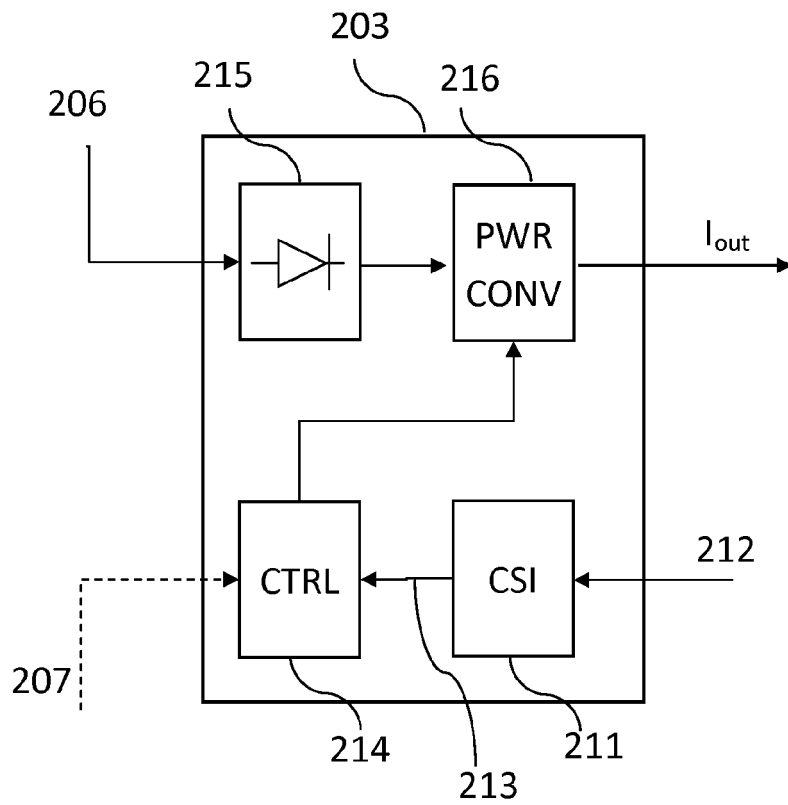


Figure 2

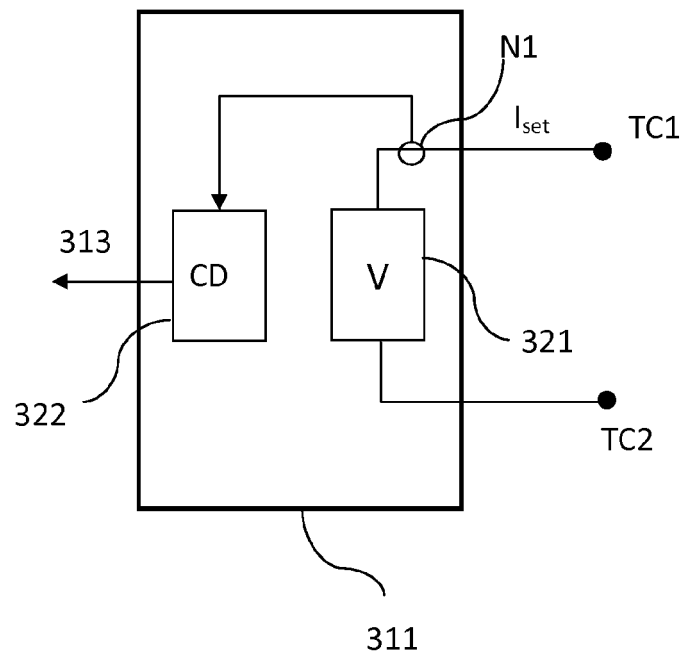


Figure 3

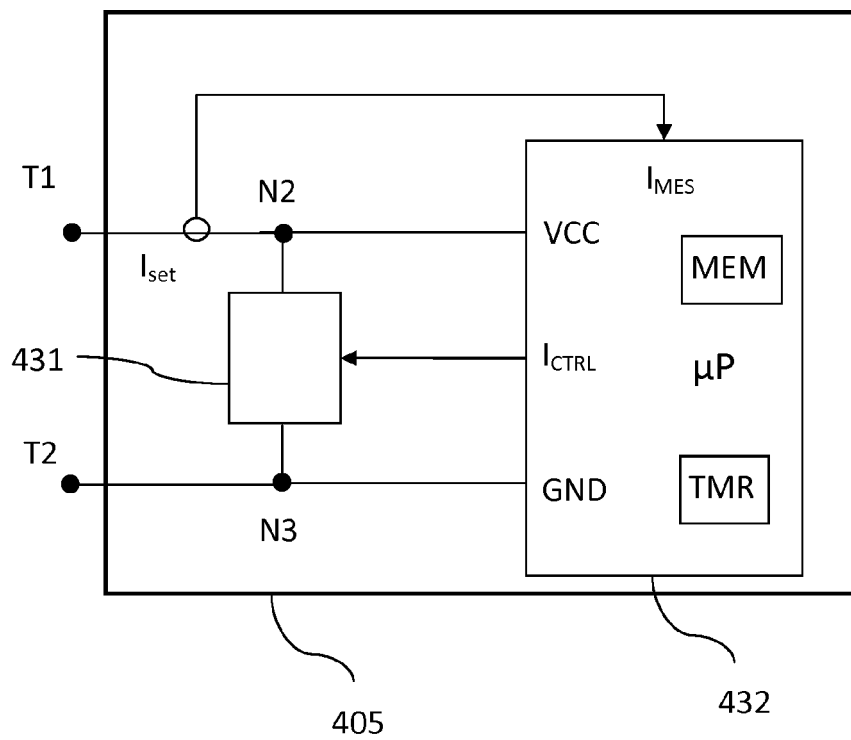


Figure 4

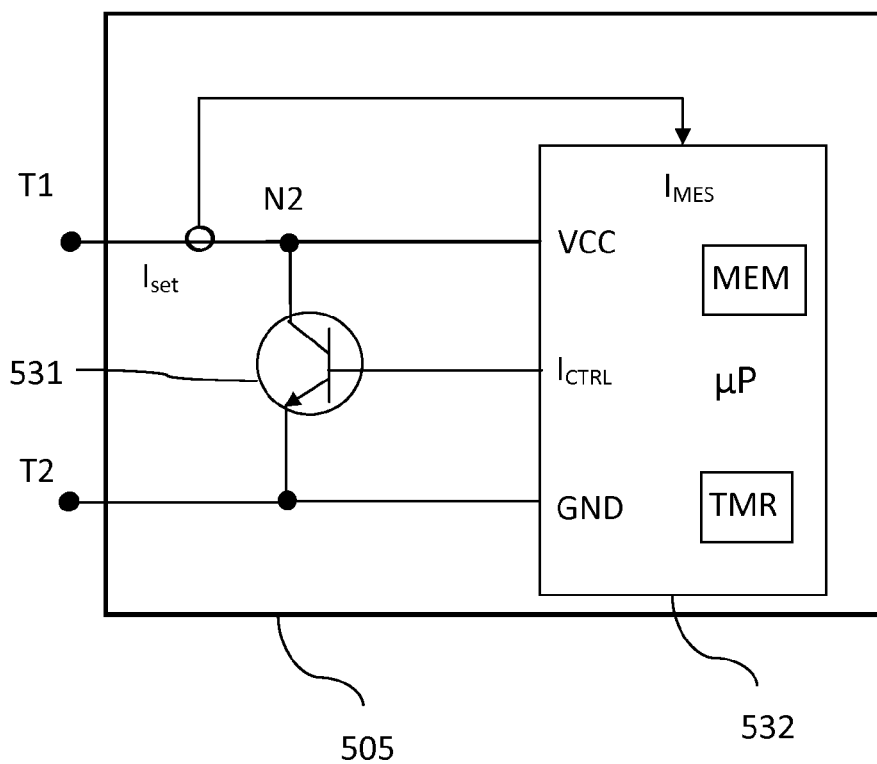


Figure 5

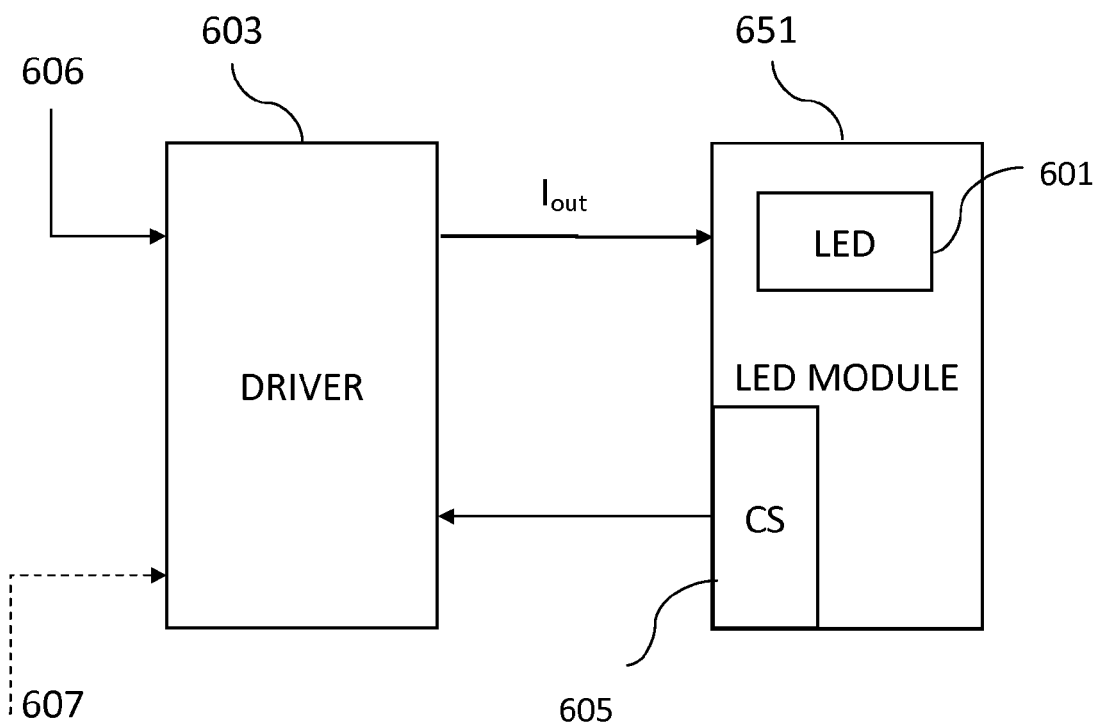


Figure 6

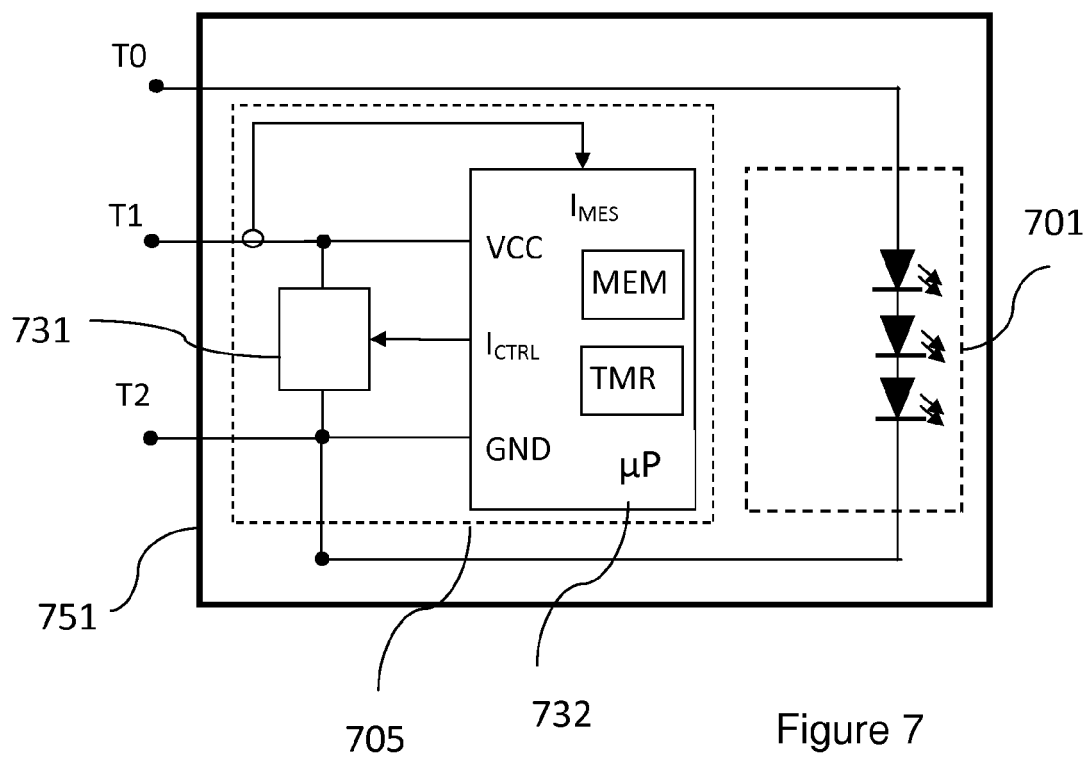


Figure 7

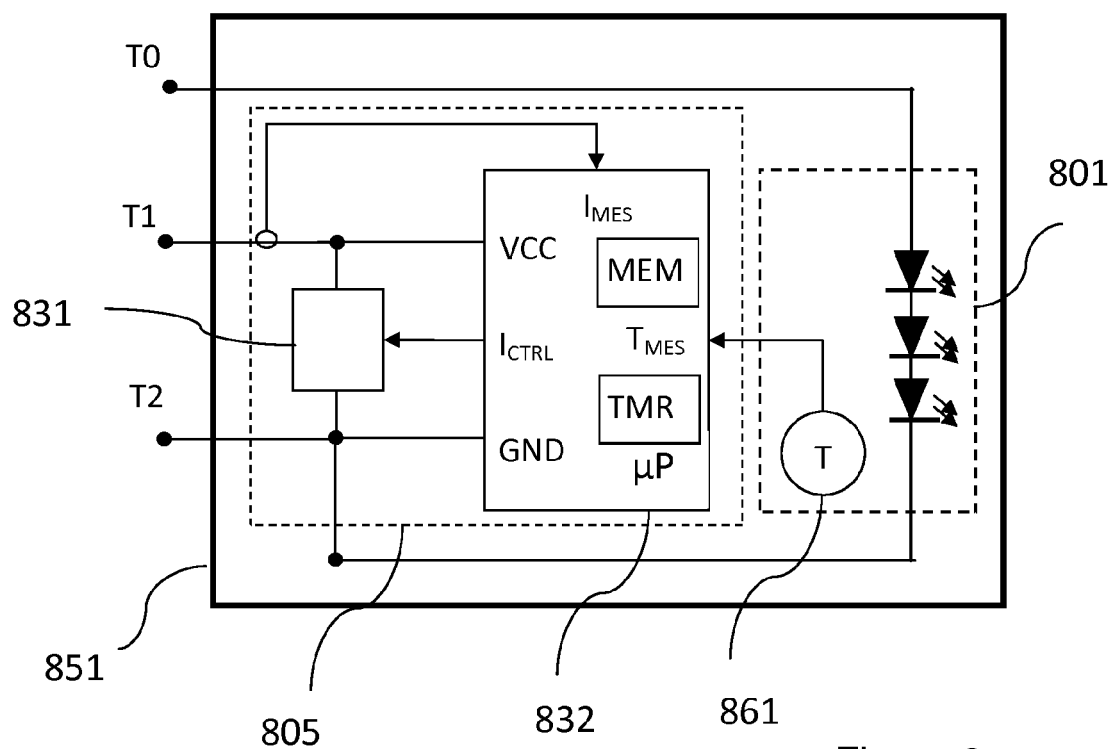


Figure 8



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Application Number
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			H05B
The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 2 February 2016	Examiner Morrish, Ian
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