(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
5 April 2012 (05.04.2012)

PCT

(10) International Publication Number
WO 2012/044223 A1

(51) International Patent Classification:
H05B 33/08 (2006.01)

(21) International Application Number:
PCT/SE2011/000139

(22) International Filing Date:
26 July 2011 (26.07.2011)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
1000801-9 29 September 2010 (29.09.2010) SE

(72) Inventor; and
(71) Applicant : VINNBERG, Andreas [SE/SE]; Östra nygatan 8, S-776 70 Vikmanshyttan (SE).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PE, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

— *with international search report (Art. 21(3))*

— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))*

(54) Title: LED LAMP

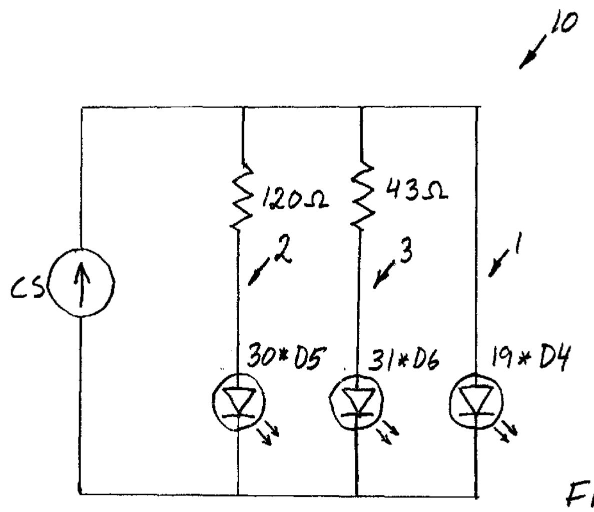

Fig.6

(57) Abstract: LED lamp adapted to be used with a single variable drive circuit, where the drive circuit comprises an analog variable voltage or current, where the lamp comprises a first LED string with at least one LED having a first wavelength, where the LED lamp comprises a second LED string with at least one LED having a second wavelength, where the first and second LED string are connected in parallel directly to the single drive circuit and where the first wavelength differs from the second wavelength such that the wavelength of the luminous flux of the LED lamp can be shifted when the current of the drive circuit is varied. The advantage of the invention is that a LED lamp that can replace a conventional incandescent lamp and that can be used with conventional dimmers is obtained.

WO 2012/044223 A1

LED LAMP

TECHNICAL FIELD

The present invention relates to a lamp comprising LED's having different wavelengths. The present invention further relates to a method for dimming a lamp comprising LED's such that it will resemble an ordinary filament lamp.

BACKGROUND ART

Nowadays, the use of regular incandescent lamps having a filament is slowly reducing. There are several reasons for this, but the most important one is environmental. Incandescent lamps have poor energy efficiency, i.e. most of the energy fed to the filament is converted to heat. Only about 5 % of the energy produce radiation in the visible range, i.e. light. The use of normal incandescent lamps is thus reduced in favour of low energy lamps, such as halogen incandescent lamps, fluorescent lamps and also LED lamps. In some countries, some types of incandescent lamps are even banned from the market in order to force the users to choose more energy-efficient light sources. For traffic and industrial use, other energy efficient lamps are also known, such as high-pressure sodium or mercury. The wavelength spectrum of these light sources makes them unsuitable for home use.

The wavelength spectrum of regular low energy lamps, i.e. of fluorescent lamps and also LED lamps is more or less acceptable for the human eye. Halogen lamps often have a somewhat higher light temperature than incandescent lamps in order to raise efficiency. Fluorescent lamps normally comprise several wavelength bands that the eye accepts as an evenly distributed range, especially the type known as “warm white”. LED lamps may have different colours, but for home use, different white LEDs are used to replace incandescent lamps. Normally, the light temperature of the white LEDs used for this purpose is higher than for an incandescent lamp, since the efficiency of a white LED is higher for LEDs having a higher light temperature.

One problem that may occur when regular incandescent lamps are replaced with low energy lamps is that the dimming function may not work with the new lamp since the dimmer is not compatible with the new lamp. There exists different solutions that will allow a fluorescent lamp to be dimmed, but the user might have to replace the existing dimmer to one suitable for a fluorescent lamp, and use special fluorescent lamps suitable for dimming. Another problem with dimming a fluorescent lamp is that the energy efficiency will degrade when the lamp is dimmed. The colour temperature of the lamp does not change very much, and will certainly not resemble that of a regular incandescent lamp being dimmed.

When a regular incandescent lamp is dimmed, the colour temperature will reduce when the brightness reduces. This behaviour resembles to a degree the colour temperature of the sun when the brightness reduces, e.g. at dawn. Such lamp behaviour is something that most users are used to and thus also would like to have for low energy lamps. At the same time, it would of course be of advantage if the energy efficiency of the lamp were the same during the dimming action. Such behaviour is not possible to obtain with a halogen incandescent lamp or a fluorescent lamp.

Halogen lamps that are connected directly to the mains may be dimmed using the same dimmer as a regular incandescent lamp. However, a halogen lamp does not differ very much from an incandescent lamp when it comes to energy efficiency. Further, the halogen lamp will normally start of at a higher colour temperature. Low voltage halogen lamps that are powered through a transformer of some kind might not be dimmed with a dimmer adapted for incandescent lamps, i.e. having a resistive load.

LED lamps may also be dimmed. Depending on the type of driving circuit, the LED lamp may also be dimmed with a dimmer adapted for incandescent lamps. At the same time, the colour temperature will stay the same or change very little since the visible light from a white LED is produced by a fluorescent material in the LED body.

WO 2009/136328 A1 describes a driving circuit for a LED light source that is adapted to be connected to a conventional phase-cut dimmer. In order to improve the dimming characteristics of the LED light source, the dimming curve of the driving circuit is non-linear. This is achieved by controlling the switched mode power supply driving the LED light source in a non-linear way.

US 2009/0026976 A1 describes a method of dimming a multi-coloured LED light source. The light source comprises several LED arrays having different coloured LEDs. In order to dim the different LED arrays, the drive cycle length of each array is controlled independently.

JP 2008263249 describes a LED lamp in which the colour of emission varies depending on the drive current. The emitted colour is a combination of the fluorescent material used and the drive current to the LED element used.

JP 2009140765 describes a LED lamp comprising a plurality of LED arrays. The LED lamp uses switches to connect the LED arrays in order to dim the lamp. The drive voltage of the lamp is driven by a PWM signal.

US 6,220,722 describes a LED lamp which may comprise LEDs with different colours, e.g. RGB coloured. The LEDs may be driven such that the colour of the light emitted by the lamp can be changed.

US 7,288,902 B1 discloses a lightning system having light sources of different colour temperatures. The light sources are arranged in different light source banks, where each light source banks is controlled individually. The voltage from a conventional dimmer is transformed by a light source driver controller and a light source driver to individually controlled currents that power the different light source banks.

US 2009/0195168 discloses a dimming control circuit for dimming light emitting diodes using a conventional dimmer for incandescent lamps. The control circuit can control multiple LED strings connected in parallel using individual drive circuits.

US 2009/0309505 discloses a method for controlling the switching of first, second and third currents in a switching sequence that is locked to the AC cycle time. The first, second and third currents are conducted through corresponding first, second and third series of color light emitting devices of different colours. The switching sequence for the different currents can be varied in order to alter the colour emission from the illumination system.

WO 2010/035155 discloses a driver for providing variable power to a LED array, which can be coupled through a dimmer to an AC power supply. The LED array can thus be controlled by a dimmer at the primary side so as to adjust its light output, and can further be utilized in currently existing lighting infrastructures.

In the above mentioned documents, different methods for dimming LED lamps are disclosed. They all utilize complicated drive circuits. Thus, there is room for an improved LED lamp that does not show the disadvantages mentioned above.

DISCLOSURE OF INVENTION

An object of the invention is therefore to solve the above-mentioned problems. More specifically, an object of the invention is to provide a LED lamp that will resemble a conventional incandescent lamp when dimmed. A further object of the invention is to provide a LED lamp with improved energy efficiency when dimmed. A further object of the invention is to provide a LED lamp that can be dimmed with a conventional dimmer adapted for incandescent lamps.

The solution to the problem according to the inventive LED lamp is described in the characterizing part of claim 1. The other claims contain advantageous embodiments and further developments of the LED lamp.

With a LED lamp adapted to be used with a single variable drive circuit, where the drive circuit comprises an analog variable voltage or current, where the lamp comprises a first LED string with at least one LED having a first wavelength, the object of the invention is achieved in that the LED lamp comprises a second LED string with at least one LED having a second wavelength, where the first and second LED string are connected in parallel directly to the single drive circuit and where the first wavelength differs from the second wavelength such that the wavelength of the luminous flux of the LED lamp can be shifted when the current of the drive circuit is varied.

By this first embodiment of the LED lamp according to the invention, it is possible to obtain a LED lamp that can be dimmed by a dimmer adapted for regular incandescent lamps. The colour temperature and thus the wavelength of the lamp will resemble the colour temperature of an incandescent lamp when dimmed, i.e. the colour temperature will be in the lower temperature range having a longer wavelength when the light output is low and will increase when the light output is increased.

The LED lamp comprises two or more LED strings connected in parallel, where each string comprises at least one LED.

All the strings are connected directly to the drive voltage or the drive current, depending on the configuration of the lamp. The different strings will have different behaviour. A string with LEDs in the lower colour temperature/longer wavelength range will light up faster than a string having LEDs in the higher colour temperature/shorter wavelength range when the drive current increases. Since the different LED strings are matched for a specific behaviour at the manufacture, there is no need for complicated drive circuits varying the drive voltage or drive current to the different string individually, e.g. using PWM signals. Instead, the lamp can be used with a single varying voltage or current and will thus be well suited as a replacement lamp for incandescent lamps.

In an advantageous development of the invention, each LED string comprises a plurality of LEDs. This will increase the efficiency of the LED lamp.

In an advantageous development of the invention, more than two LED strings are used in the LED lamp. In this way, the colour temperature/wavelength behaviour of the LED lamp can be improved further.

In an advantageous development of the invention, the LED lamp further comprises a drive circuit. By incorporating a drive circuit in the LED lamp, the LED lamp can be used as a direct replacement of a regular incandescent lamp connected to a conventional dimmer.

In an advantageous development of the invention, the LED lamp is supplied with a lamp socket. The advantage of this is that the LED lamp can be used as a replacement lamp in an easy way.

BRIEF DESCRIPTION OF DRAWINGS

The invention will be described in greater detail in the following, with reference to the embodiments that are shown in the attached drawings, in which

Fig. 1 shows a first example of a LED lamp according to the invention,

Fig. 2 shows a graph of the relation between drive current and colour temperature of the lamp according to Fig. 1,

Fig. 3 shows a graph of the relation between drive current and luminous flux of the lamp according to Fig. 2,

Fig. 4 shows a second example of a LED lamp according to the invention,

Fig. 5 shows a third example of a LED lamp according to the invention,

Fig. 6 shows a fourth example of a LED lamp according to the invention,

Fig. 7 shows a graph of the relation between drive current and colour temperature of the lamp according to Fig. 6,

Fig. 8 shows a schematic drive circuit adapted to be used with the LED lamps according to the invention,

Fig. 9 shows a LED lamp with an integrated drive circuit adapted for 230 volts according to the invention.

MODES FOR CARRYING OUT THE INVENTION

The embodiments of the invention with further developments described in the following are to be regarded only as examples and are in no way to limit the scope of the protection provided by the patent claims.

The colour temperature obtained by mixing LEDs having different wavelengths is related to the Planckian locus or the black body radiance. The Planckian locus is found in the CIE 1931 chromaticity diagram. The colour temperature for a specified set of LEDs can be estimated by projecting the wavelengths to the Planckian locus curve of the diagram. This is well known to the skilled person. This gives the relation between the colour temperature and the wavelength of a LED string. Thus, a LED string can be said to have a wavelength or a colour temperature even though the luminous flux of the LED string comprises several narrow wavelengths. This can be seen as the mean value for the wavelength or colour temperature. When a LED string is referred to as having a wavelength, the mean value of the wavelengths of the different LEDs in the LED string is referred to.

The LED lamp circuit that is described is mainly intended to be used in a replacement lamp for incandescent lamps that are powered by the mains, i.e. powered by a 230-volt or 115-volt alternating voltage system, and that are powered through a dimmer. However, such a lamp circuit can of course also be adapted for the use with low-voltage drivers, such as 12 V or 24 V direct or alternating voltage drivers used in e.g. vehicles, or to any other voltage available in another system. The simplicity of the inventive circuit will display the same advantages regardless of the driving voltage. In the examples below, theoretical LEDs with an ideal voltage drop and no resistive component are used for the simplicity of the explanations. Nevertheless, in the examples shown, real LEDs having a somewhat nonlinear behaviour are essential for the function of the shown circuits. It is the parasitic components, mainly the resistive component, of the LEDs that makes the proposed circuits work well for dimming LEDs.

In all the described circuits, the current through the LED strings is varied. When the lamp is connected to a variable voltage source, which will be the case when the lamp is used to replace an incandescent lamp, the variable voltage source will thus cause a variable current to be driven through the LED strings. When the lamp is used in other applications, e.g. when it is integrated with a drive circuit in a stand-alone unit, it is also possible to use a variable current source to dim the lamp.

The most common type of a conventional dimmer that is used for incandescent lamps is the leading edge dimmer due to its simple construction and thus its low cost. In such a dimmer, a triac is fired after a user-controlled time interval which then starts to conduct and continuous to conduct until the AC voltage passes its zero-crossing. At that time, the triac turns off and the process is repeated.

A newer type of dimmer is the tailing edge dimmer, or sometimes called a "transistor dimmer". A tailing edge dimmer works in a similar way but instead of turning on after a certain amount of time after a zero-crossing, the transistor is instead turned off after a user set time interval. This dimmer type has the advantage of reducing the requirements on the capacitors, diodes and inrush limiters in electronic transformers, fluorescent ballasts and LED bulbs.

Older types of dimmers include rheostats and autotransformers that either resistively or magnetically reduce the amplitude of the entire AC cycle without cutting either the leading of tailing edge.

In order to control a LED lamp, there are several ways to detect the requested dim level set by the user. For tailing or leading edge dimmers, one way is to measure the conduction time, the off time or the firing angle (all related to each other in these dimmer topologies) and control the light output from that value. These possibilities have the advantage of being insensitive to voltage variations in the mains and also to the nominal voltage of the power system, e.g. 115 or 230 V systems. If the average or RMS rectified voltage is measured, both autotransformers and rheostats can be used to dim the LED lamp, at the expense of sensitivity to mains variations and energy efficiency.

A known LED lamp adapted to replace an incandescent lamp is provided with a string of white LEDs that will provide the essential light output when the lamp is driven with the nominal voltage, i.e. when it is not dimmed. The drive source for a LED lamp is normally a current source. In order to make the LED lamp energy efficient and also simple, the string comprises a plurality of LEDs. The string may also comprise a current limiting resistor and/or a capacitor. The number of LEDs is adapted for the voltage of the driver circuit in order to match the driver voltage with the forward voltage drop of the combined number of LEDs. A lamp of this kind will work well in replacing a regular incandescent lamp when the drive voltage is not dimmed. When such an LED lamp is dimmed, the brightness of the lamp will reduce somewhat down to a point when the combined voltage drop over the LEDs reaches a trip value. At this point, the lamp will go out. During the dimming, the energy efficiency of the lamp will in fact increase but the price to be paid is low efficiency at full current. Also, the colour temperature and wavelength will stay the same throughout the complete dimming cycle.

In the inventive lamp, one or more LED strings are added to the lamp and are connected in parallel to the first string. A first example of the inventive LED lamp circuit is shown in Fig. 1, where the LED lamp is driven by a current source CS. In this embodiment, the LED lamp 10 comprises a first string 1 with one white LED D1. The lamp further comprises a second string 2 connected in parallel with the first string. The second string comprises a red LED D2 and also a current limiting resistor R2 in series with the red LED D2. In the embodiment shown in Fig. 1, D1 is a white LED with a forward voltage drop of 3.7 V at 20 mA, D2 is a red LED with a forward voltage drop of 2.0 V at 20 mA and R2 is an 85 ohm resistor. As long as the drive current is below 20 mA, only the red LED will light up.

Over 20 mA, the white LED will light up proportionally with the current excessive of 20 mA.

In this simple configuration, the lamp will start with only a red light at a relatively low level, and with an increased current, the white light will eventually supersede the red light. A graph showing a typical colour temperature T for this lamp type as a function of the drive current I is shown in fig. 2. Figure 3 shows the luminous flux F in lumen for the same lamp as a function of the drive current I. As can be seen, the brightness of the lamp can be varied continuously from zero to full brightness and the colour temperature will vary continuously from red to white over the larger part of the brightness range.

A second example of the inventive LED lamp is shown in Fig. 4. In this example, the LED lamp comprises a first LED string 1 with two white LEDs D1. The lamp further comprises a second string 2 connected in parallel with the first string. The second string comprises three red LEDs D2 and also a current reducing resistor R2 in series with the LEDs. As in the first example, D1 is a white LED with a forward voltage drop of 3.7 V at 20 mA, D2 is a red LED with a forward voltage drop of 2.0 V at 20 mA. Here, R2 is a 70 ohm resistor. In this example, the voltage drop of the LEDs in the two strings is matched to a higher degree. This will improve the energy efficiency of the lamp. As in the first example, the white LEDs, i.e. the LEDs of the first string, will not light up when the drive current is below 20 mA. When the drive current exceeds 20 mA, the white LED's will light up proportionally with the current excessive of 20 mA.

The number of LEDs in a string is adapted for the voltage of the driver circuit in order to match the driver voltage with the forward voltage drop of the combined number of LEDs in each string. A resistor may be used in a string to balance the current through a string, or increase the string's forward voltage at the designed maximum current to match that of the other strings connected in parallel to it. In the shown examples, the colour temperature will start at a low colour temperature and will remain at that colour temperature over a small brightness range and will then start to rise until the final, higher colour temperature is reached. Depending on the used (non-ideal) LEDs, the colour temperature will vary over a larger portion of the dimming range, or may even vary over the complete range.

In a third example, as shown in Fig. 5, the lamp comprises three LED strings connected in parallel. The first string 1 comprises two white LEDs D1. The second string 2 comprises two red LEDs D2 and also a current limiting resistor R2 in series with the LEDs. The third string 3 comprises three yellow LEDs D3 and a resistor R3. D1 is a white LED with a forward voltage drop of 3.7 V at 20 mA, D2 is a red LED with a forward voltage drop of 2.0 V at 20 mA and D3 is a yellow LED with a forward voltage drop of 2.0 V at 20 mA. Here, R2 is a 170 ohm resistor and R3 is a 70 ohm resistor. In this example, the second string 2 will light up first and will relatively soon be superseded by the third string 3 that in turn will be superseded by the first string 1 when the current is increased. In this way, a smoother brightness variation is obtained. At the same time, the colour temperature variation will better resemble a conventional incandescent lamp when the lamp is dimmed and the colour rendering will improve due to more colours mixed. Also, as a second order effect, the use of several single-band colour LEDs in the longer-wavelength part of the spectrum will allow the use of higher colour temperature of the white LEDs, which will minimize losses due to Stokes shift/wavelength downmixing, further increasing the efficiency of the LED lamp.

The number of LED strings in the lamp may vary and can be chosen depending on the required end result and the voltage of the system in which the lamp is to be used. The number of LEDs in each string is chosen depending on the drive voltage for which the lamp is adapted. The types of LEDs in a string may also be chosen depending on the required end result. It is possible to mix different types of LEDs in a single string in order to obtain the required colour temperature of the lamp during the dimming of the lamp. It is however important to use several parallel LED strings in order to obtain a colour shift when dimming. The use of a resistor in a string and the value for that resistor is also selected depending on the drive voltage. Also the colour of the LEDs used, both in total and in each string, can be varied in order to obtain a lamp that resembles a regular incandescent lamp.

Fig. 6 shows a further example of an inventive LED comprising a circuit with 80 LEDs, each driven with a maximum current of 20 mA. The LEDs are divided into three strings, a first string 1 with 19 white LEDs D4, a second string 2 with 30 red LEDs D5 and a 120 ohm resistor and a third string 4 with 31 yellow LEDs D6 and a 43 ohm resistor. D4, D5 and D6 may be the same LEDs as D1, D2 respectively D3, or may be other LEDs having different colour and/or voltage drop. Fig. 7 shows a graph of the colour temperature of the lamp of Fig. 6. As can be seen by graph 20, the colour temperature T varies from 2000 K to 3400 K during the dimming action. The slope of the graph is relatively steep at the beginning, i.e. at a low drive current, but flattens out when the current raises. Such a relation between brightness and colour temperature gives a good approximation of the behaviour of a conventional incandescent lamp when dimmed. The graph 21 shows the voltage V across the circuit, graph 24 shows the current I through the first string 1, graph 22 shows the current I through the second string 2, and graph 23 shows the current I through the third string 3. All the graphs are related to the x-axis which shows the total current TI delivered by the current source CS.

It is also possible to use LEDs with different colour temperature in the same string. In this way, one string may e.g. comprise both red and yellow LEDs that will start to light at a low current and another string may comprise white LEDs that are configured to light up at a higher current. The number of LEDs used in a string may also depend on the light output from the LEDs. The total number of LEDs used in the lamp will set the light output for the lamp when driven with the full voltage, i.e. when not dimmed.

The LED lamp is adapted to be used with a drive circuit that converts the input voltage to a drive current. The drive circuit is thus well adapted to be used with a conventional dimmer having a variable voltage output. The drive circuit uses the actual input voltage to control the power stage in dependency of the input voltage. The current supplied to the LED lamp will thus be a function of the input voltage. Such a circuit will reduce the energy loss in the LED lamp. The circuit can also, by using a mean value function, reduce the sensitivity of the LED lamp to short term voltage variations in the mains voltage system. This is especially advantageous for weaker power systems, e.g. in development countries, where large variations in the voltage is common. It is also advantageous when the same power system powers high current devices that switches on and off at a high rate, such as electric through-flow water heaters.

Fig. 8 shows a schematic drive circuit adapted to be used with the LED lamp 10 according to the invention. The circuit is adapted to be connected to a regular dimmer at the input connections CN. The circuit comprises in this example a mains filter MF, a rectifier bridge R, a low-pass filter LP and a power stage PS that will convert the input voltage to drive current to drive the LED lamp 10. The circuit further comprises a dimming sensor DS that sends a control signal to the power stage. The control signal is depending on the input voltage to the dimming sensor, i.e. on the voltage outputted from the regular dimmer. If the drive circuit is connected directly to the mains, it is also possible to integrate a dimming means, such as a potentiometer, in the dimming sensor. Different drive circuits are possible to use, both buck converters and boost converters or a combination of both, depending on the supply voltage and the used numbers of LEDs in the LED lamp. A buck converter is a step-down converter that converts an input DC voltage to a lower output DC voltage. A boost converter converts an input DC voltage to a greater output DC voltage. Preferably, a buck converter is used when the LED lamp is adapted to be used with a conventional dimmer in a mains voltage system.

Fig. 9 shows a LED lamp with an integrated buck converter drive circuit that can be used as a replacement bulb for e.g. 230 volts. The circuit is one example of the schematic circuit shown in Fig. 8. The LED lamp 10 is adapted to be connected to a regular dimmer TD via the connection CN. The regular dimmer TD is connected to the mains AC. The drive circuit comprises an input EMI mains filter comprising of e.g. two inductors I and two capacitors C and a rectifier bridge comprising four diodes D. The drive circuit further comprises a triac trigger circuit in order to maintain the hold current in the regular dimmer TD comprising a resistor R_{10} and a capacitor C_{10}. The input voltage sensing is done by the dimming sensing circuit comprising R_{11}, R_{12}, C_{11}, R_{13} and TR_{10}, which output S_{10} is used to control the integrated circuit IC of the power stage. Diode D_{10} prevents reverse voltage to the input and C_{12} is an energy storage capacitor.

The power stage further comprises a low voltage generation circuit comprising R_{14}, D_{11} and C_{13}, which generates a low voltage, e.g. 5 to 15 volts, that is used to power the IC and for the current feedback obtained by R_{15} and OP_{10}. The control signal S_{10} is mixed with the current feedback signal S_{11} at the feedback pin FB of the IC. A compensation network comprising R_{16} and C_{14} is connected between the feedback pin FB and the compensation pin CP of the IC. The output of the IC controls the switch transistor TR_{11} which controls the LED lamp through a buck inductor I_{10}. The switch transistor is controlled by the dimming sensing circuit and the IC that shuts the transistor on and off depending on the input voltage from the regular dimmer. The drive circuit also comprises a buck diode D_{12}.

The IC may be a switch mode PWM IC that switches the switch transistor TR_{11}, which in this example is an N-channel MOSFET transistor. The LED lamp 10 is connected between the buck inductor I_{10} and the current sensing resistor R_{15} used to measure the current through the LED lamp. In the shown example, the LED lamp 10 is connected in parallel with a smoothing capacitor C_{15}. The LED lamp 10 comprises a first LED string 1 and a second LED string 2, where the second LED string also comprises a resistor. The first comprises at least one LED having a relatively high forward voltage drop, whereas the second LED string comprises at least one LED having a lower forward voltage drop. More LED strings may also be connected in parallel with the first and second LED string. The LED lamp 10 may e.g. be the LED lamp shown in Fig. 6.

The composition of a lamp, i.e. the colour behaviour during the dimming of the lamp, may also be adapted to different markets. In some markets, there may be a desire to use lamps with a somewhat lower colour temperature, resembling incandescent lamp. In other markets, lamps with a higher colour temperature resembling fluorescent lamps may be more popular. With the inventive circuit, it is easy to obtain any desired lamp behaviour in an easy and cost-effective way, without the need of a specific drive circuit.

The invention is not to be regarded as being limited to the embodiments described above, a number of additional variants and modifications being possible within the scope of the subsequent patent claims. The types and numbers of LED's may be altered.

CLAIMS

1. LED lamp (10) adapted to be used with a single variable drive circuit, where the drive circuit comprises an analog variable voltage or current, where the LED lamp (10) comprises a first LED string (1) with at least one LED having a first wavelength, characterized in that the LED lamp (10) comprises a second LED string (2) with at least one LED having a second wavelength, where the first and second LED strings (1, 2) are connected in parallel directly to the single drive circuit and where the first wavelength differs from the second wavelength such that the wavelength of the luminous flux of the LED lamp can be shifted when the current (CS) of the drive circuit is varied.

2. LED lamp according to claim 1, characterized in that the second LED string (2) comprises a resistor (R2) is connected in series with the LED.

3. LED lamp according to claim 1 or 2, characterized in that the second LED string (2) comprises a plurality of LEDs connected in series.

4. LED lamp according to claim 1 to 3, characterized in that the first LED string (1) comprises a plurality of LEDs connected in series.

5. LED lamp according to claim 1 to 4, characterized in that the LED lamp further comprises a third LED string (3) comprising a plurality of LEDs with a third wavelength and a resistor (R3) connected in series, where the third LED string is connected in parallel with the first LED string (1) and the second LED string (2).

6. LED lamp according to claim 1 to 5, characterized in that the second LED string (2) is adapted to light up before the first LED

string (1) in that the forward voltage drop of the second LED string is lower than the forward voltage drop of the first LED string.

7. LED lamp according to claim 5 or 6, characterized in that the second LED string (2) is adapted to light up before the third LED string (3) and that the third LED string (3) is adapted to light up before the first LED string (1) in that the forward voltage drop of the second LED string is lower than the forward voltage drop of the third LED string and that the forward voltage drop of the third LED string is lower than the forward voltage drop of the first LED string.

8. LED lamp according to any of the preceding claims, characterized in that the second LED string (2) comprises at least two different types of LEDs having different wavelengths.

9. LED lamp according to any of the preceding claims, characterized in that the LED lamp further comprises a drive circuit.

10. LED lamp according to claim 9, characterized in that the LED lamp is adapted to be driven by a mains dimmer.

11. LED lamp according to any of the preceding claims, characterized in that the lamp is mounted to a lamp socket.

12. LED lamp according to any of claims 9 to 11, characterized in that the drive circuit is a step-down converter.

13. LED lamp according to any of claims 9 to 11, characterized in that the drive circuit is a step-up converter.

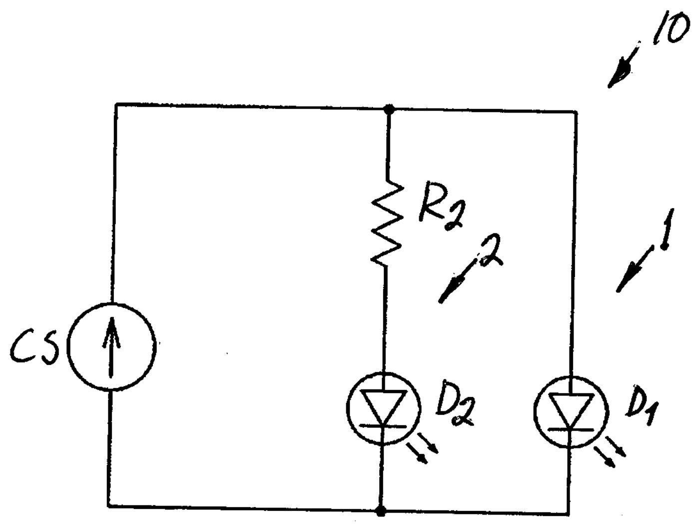

Fig. 1

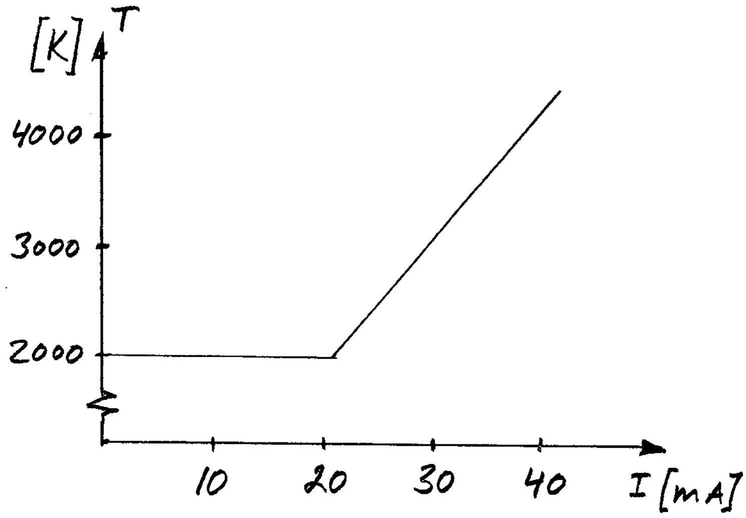

Fig. 2

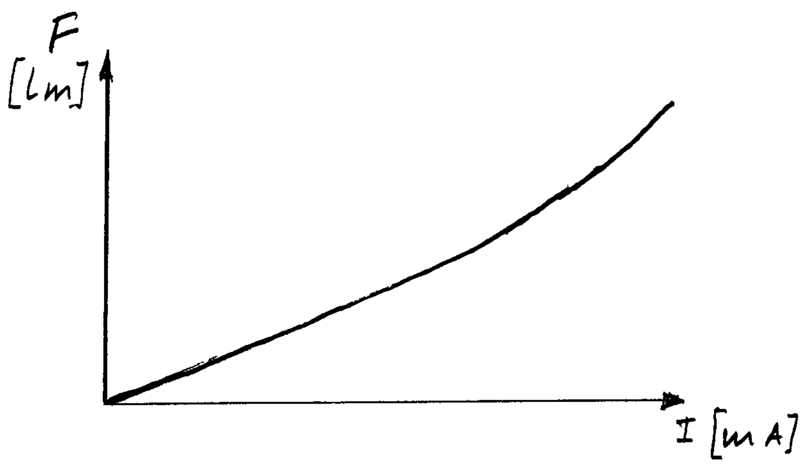

Fig. 3

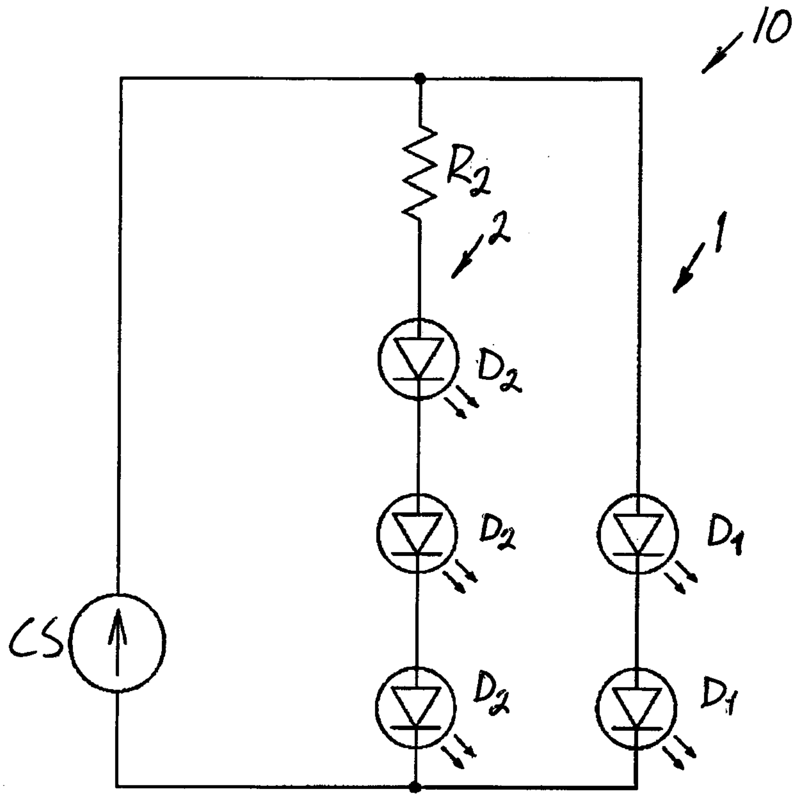

Fig. 4

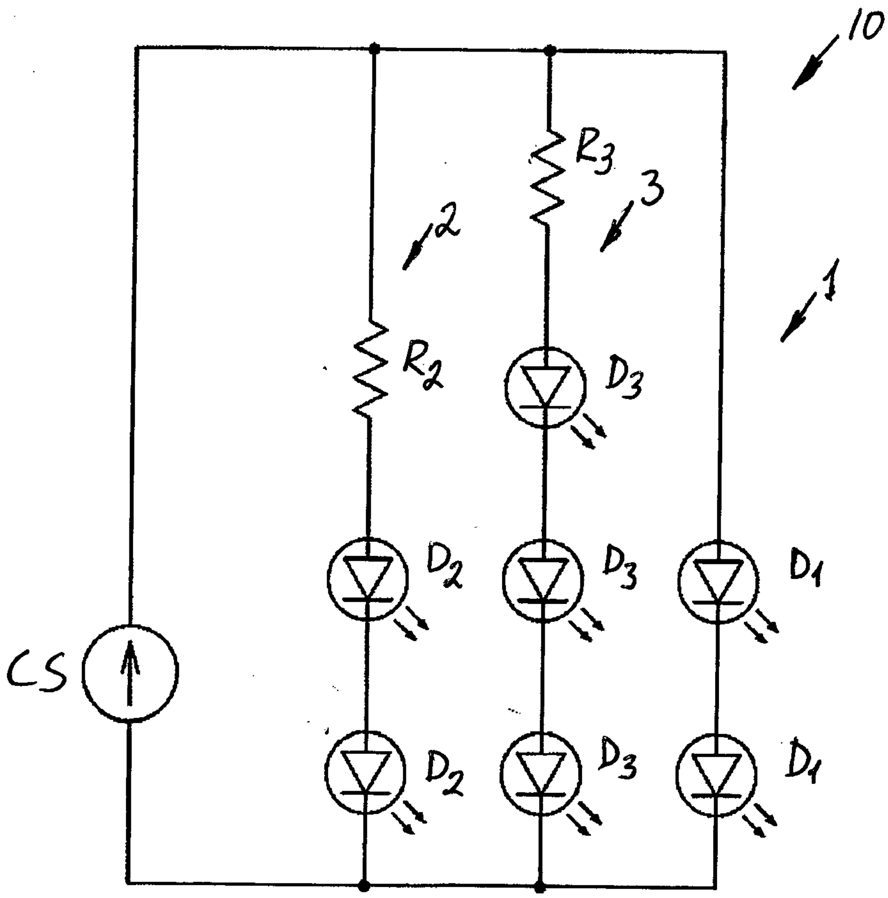

Fig. 5

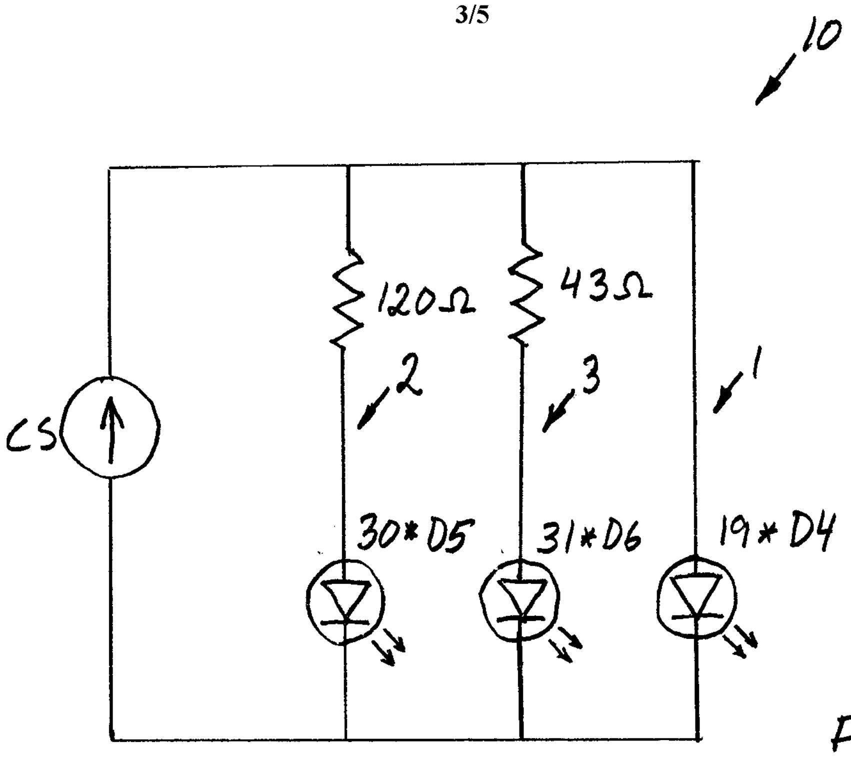
10
120Ω
43Ω
2
3
1
CS
30*D5
31*D6
19*D4

Fig.6

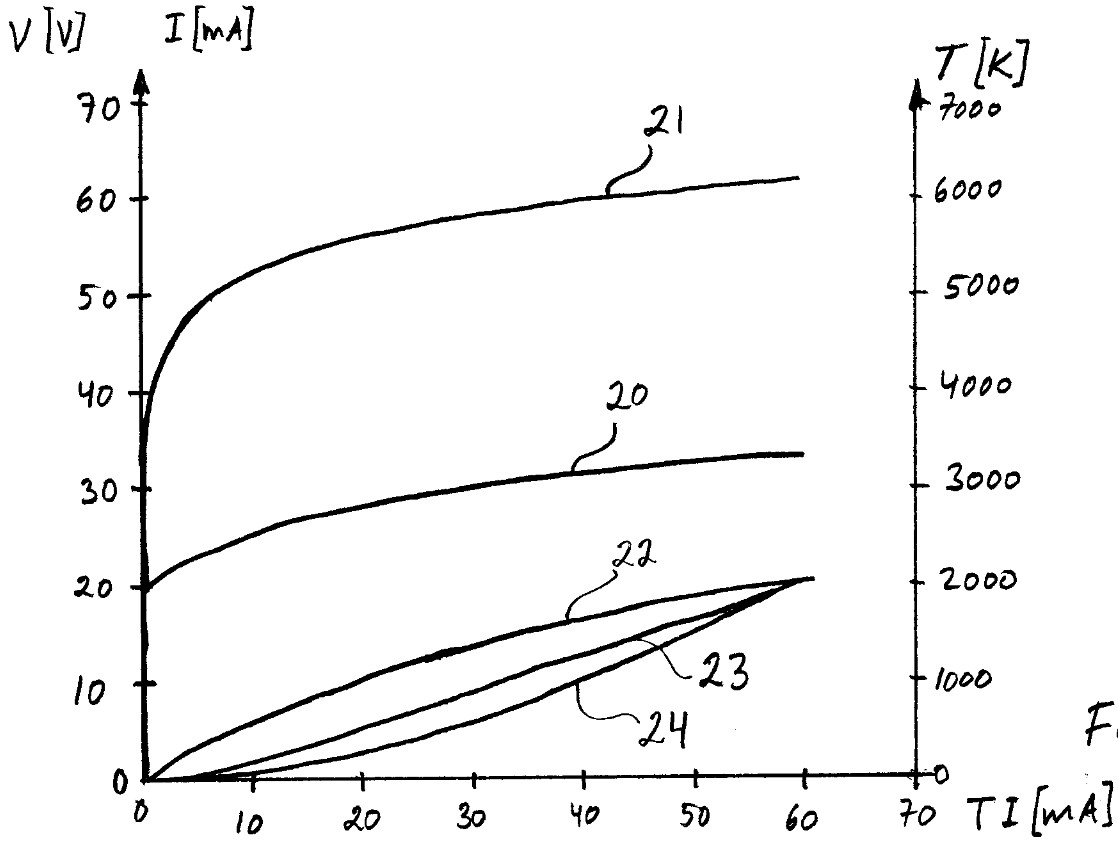
V [V]
I [mA]
T [K]
70
60
50
40
30
20
10
0
7000
6000
5000
4000
3000
2000
1000
0
21
20
22
23
24
0
10
20
30
40
50
60
70
TI [mA]

Fig.7

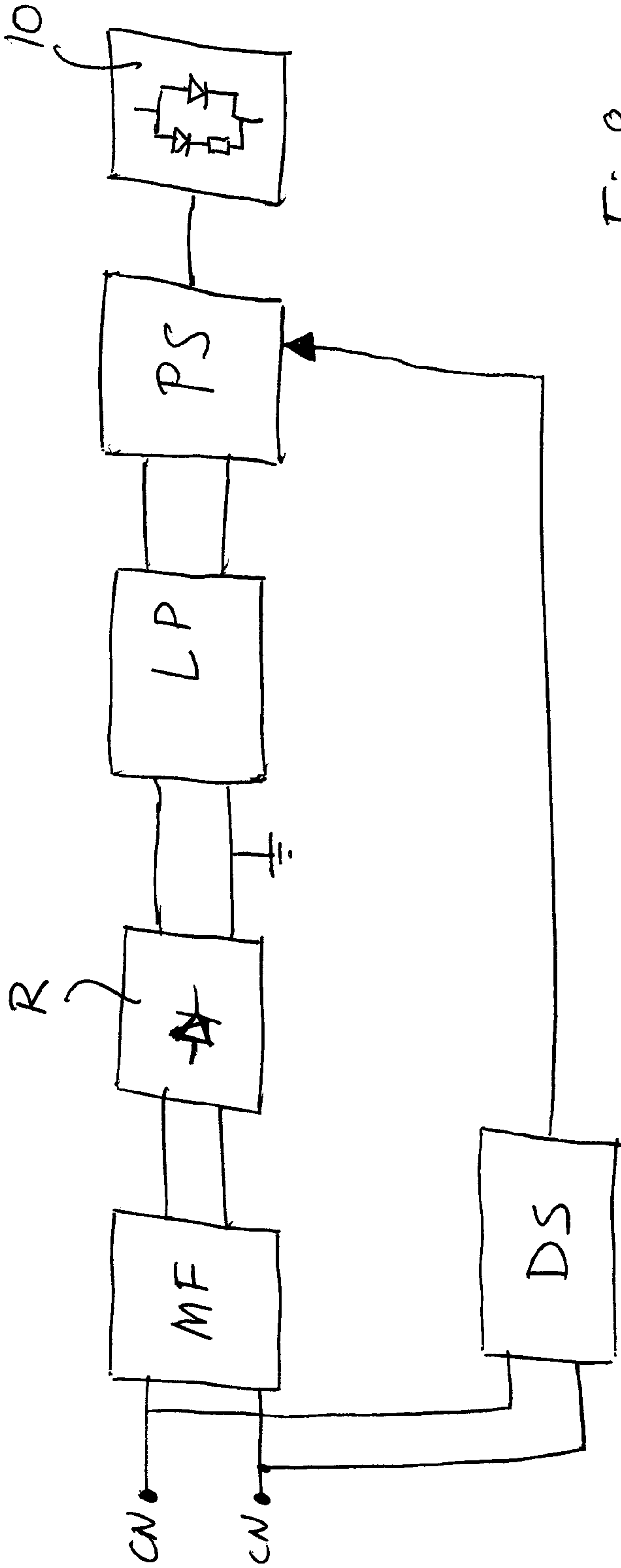

Fig. 8

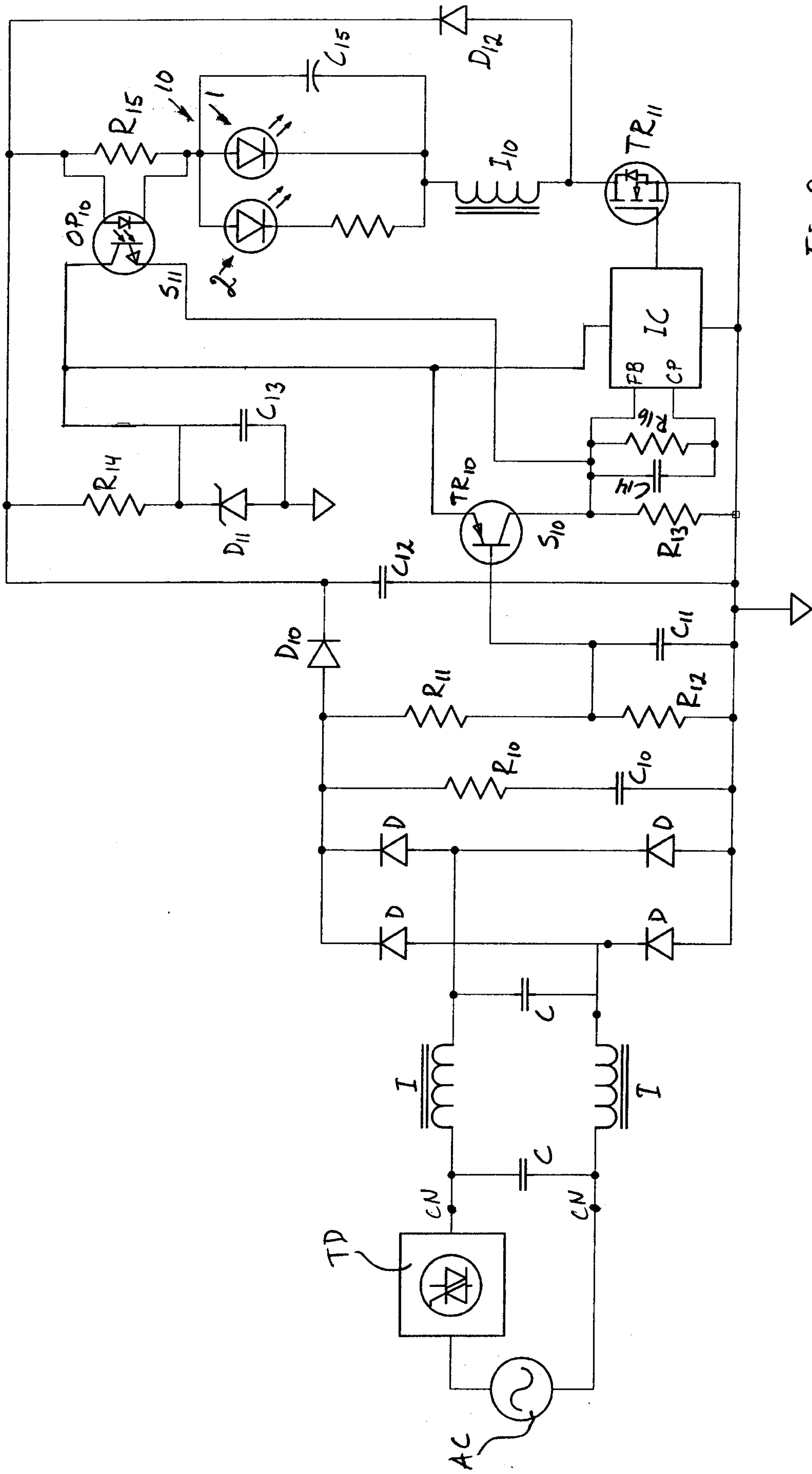
D12
C15
R15
10
1
TR11
I10
OP10
2
S11
IC
FB
CP
R16
C14
C13
R14
D11
TR10
S10
R13
C12
D10
C11
R11
R12
R10
C10
D
D
D
D
C
I
I
C
CN
CN
TD
AC

Fig. 9

INTERNATIONAL SEARCH REPORT

International application No
PCT/SE2011/000139

A. CLASSIFICATION OF SUBJECT MATTER
INV. H05B33/08
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H05B H01L F21V

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2008/203945 A1 (DEURENBERG PETER HUBERTUS FRANCISCUS [NL] ET AL) 28 August 2008 (2008-08-28) paragraph [0002] - paragraph [0038]; claims 1-4, 8; figures 1, 3-5 -----	1-13
X	US 2008/203936 A1 (MARIYAMA MITSURU [JP] ET AL) 28 August 2008 (2008-08-28) paragraph [0003] - paragraph [0165]; figure 5 -----	1-13
X	US 2007/145349 A1 (LU MING [TW] ET AL) 28 June 2007 (2007-06-28) column 1, line 62 - column 5, line 51 ----- -/--	1-13

[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier document but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
13 February 2012	20/02/2012

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Hernandez Serna, J

2

Form PCT/ISA/210 (second sheet) (April 2005)

INTERNATIONAL SEARCH REPORT

International application No
PCT/SE2011/000139

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2007/291467 A1 (NAGAI HIDEO [JP] ET AL) 20 December 2007 (2007-12-20) paragraph [0044] - paragraph [0145]; figure 9c -----	1-13
A	WO 2008/152922 A1 (SHARP KK [JP]; ROSHAN RAKESH; HADWEN BENJAMIN JAMES; MONTGOMERY DAVID) 18 December 2008 (2008-12-18) -----	1-13

2

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/SE2011/000139

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2008203945 A1	28-08-2008	AT 537686 T	15-12-2011
		CN 101185375 A	21-05-2008
		EP 1889518 A2	20-02-2008
		JP 2008542990 A	27-11-2008
		KR 20080031686 A	10-04-2008
		US 2008203945 A1	28-08-2008
		WO 2006126124 A2	30-11-2006
US 2008203936 A1	28-08-2008	CN 101257750 A	03-09-2008
		JP 4430084 B2	10-03-2010
		JP 2008218043 A	18-09-2008
		KR 20080080012 A	02-09-2008
		US 2008203936 A1	28-08-2008
US 2007145349 A1	28-06-2007	CN 101331800 A	24-12-2008
		US 2007145349 A1	28-06-2007
		WO 2007071170 A1	28-06-2007
US 2007291467 A1	20-12-2007	EP 1790199 A1	30-05-2007
		JP 2008505433 A	21-02-2008
		US 2007291467 A1	20-12-2007
		WO 2006001221 A1	05-01-2006
WO 2008152922 A1	18-12-2008	GB 2458095 A	09-09-2009
		JP 2010529590 A	26-08-2010
		US 2010182294 A1	22-07-2010
		WO 2008152922 A1	18-12-2008