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(54) **A lighting module having multiple LEDs and adjustable trimming elements and a method of individually adjusting such trimming elements**

(57) The invention relates to a lighting module comprising a plurality of light emitting diodes (LEDs) connected in a circuit comprising a plurality of parallel strings, each said string including at least one LED, wherein at least one trimming element is connected in series with each said string, and wherein a characteristic value of at least some of the trimming elements is individually adjustable to control a current and/or a voltage in the corresponding string.

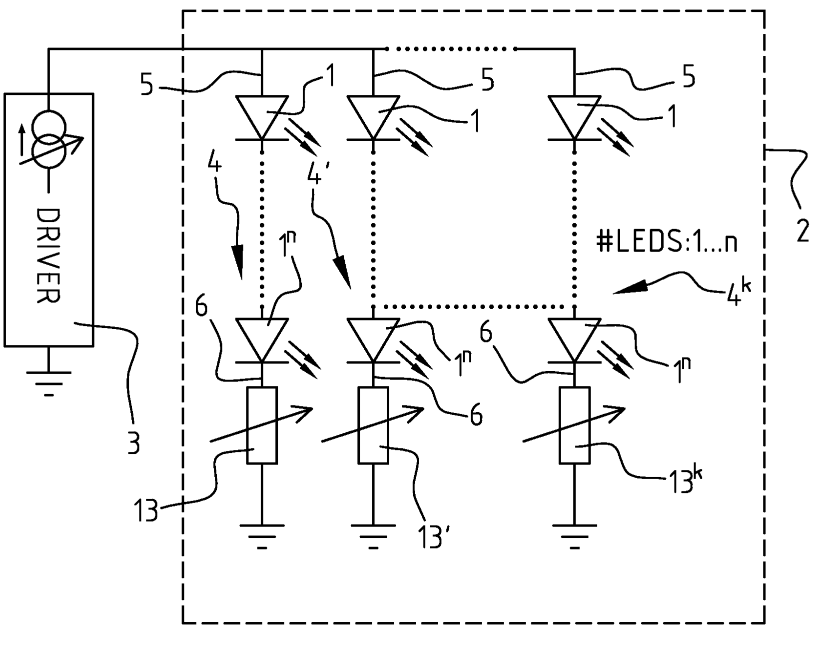

FIG. 10

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Description

Technical field

[0001] Various embodiments of the invention relate generally to the trimming of parallel connected LED strings in a lighting module in order to accurately adjust one of the module's primary performance parameters.

Background

[0002] LED light sources often contain a plurality of light emitting diodes (LEDs) mounted on a support. Such an arrangement is used when a single LED light source is not acceptable, e.g. for reasons of design or performance, or if the spot intensity is too high. Further, the use of a single light source may not be feasible for technical or commercial reasons, e.g. because it would require too much power or because a specific color has to be generated. The solution then is a module including multiple LEDs, where the combination of the LEDs produces the desired light level and optical characteristics.

[0003] Conventionally, an arrangement including a plurality of LEDs 1 in a module 2 can be driven in either of five ways.

[0004] A first option is for each of the LEDs 2 to be individually driven by a separate driver 3 (Fig. 1). This option is rarely used due to the extremely high costs of the multiple drivers 3, combined with high system complexity. In that respect it should be noted that a typical LED module may include tens of LEDs, rather than the four LEDs shown in Figure 1.

[0005] Alternatively, the LEDs 1 can be connected in series and driven by a common driver 3 as a single string 4 of LEDs 1 (Fig. 2). This results in a setup where a (fluctuating) voltage is applied to the extremities 5, 6 of the LED string 4, resulting in an identical current flowing through all the individual LEDs 1 in the string 4. This is very desirable for the LEDs 1, but has the drawback that the total voltage on the string 4 might have to be limited for reasons of electrical safety and power supply efficiency.

[0006] It is also conceivable for the LEDs 1 to be connected in multiple parallel strings 4, 4', ..., 4^k of LEDs 1 (Fig. 3). In this configuration, each string 4 may contain either a single LED 1 or a plurality of LEDs 1, bearing in mind that the number of LEDs 1 in each string 4 will be the same. The positive extremities 5 of all strings 4 are connected to each other and to a common driver 3, while the negative extremities 6 are all connected to earth. The advantage of this setup is that the voltage level in each string 4 can be adjusted to design limits of the LEDs 1. The drawback is the expense and complexity of providing multiple parallel strings 4. The major disadvantage of this setup is that the current per string 4 will fluctuate and will depend to a great extent on the physical performance parameters in voltage and (dynamic) resistance of each LED. Due to this spread, the resulting current per string may fluctuate greatly and thus the individual current per LED may fluctuate with it. Higher currents cause higher operating temperatures of the LEDs, resulting in faster aging and faster performance drop-off in comparison to LEDs driven at lower currents.

[0007] The LEDs can also be connected in a matrix of multiple parallel strings 4, wherein each LED 1 in a string 4 is connected to LEDs 1 in adjacent strings 4 (Fig. 4). The LEDs 1 are interconnected on each horizontal row 8 in order to balance the voltage drops per parallel set and to reduce the maximum unbalance in current for each LED 1. The major dependency on LED physical parameters that was noted above as a drawback of the parallel arrangement still exists in this matrix arrangement. The unreliability and the current spread between the highest and lowest elements in the same positions in the strings will increase with the number of parallel strings 4 in the matrix 7.

[0008] And finally, the LEDs can be connected in multiple parallel strings 4 in series with a stabilising resistor 9 (Fig. 5). Here again, each string 4 may include one or more LEDs 1, with the number of LEDs 1 being equal for all strings 4. The positive extremities 5 of all strings 4 are connected to each other and to a common driver 3, while each negative end 6 is connected to a respective stabilising resistor 9. These stabilising resistors 9, 9', ..., 9^k in turn are connected to earth. The major advantage of this arrangement is that the unbalance in current per string 4 can be reduced. On the other hand, the voltage on each string will increase, while the total efficiency will decrease and extra heat dissipation will occur in the stabilising resistors.

[0009] Just like individual LEDs may be grouped to form a lighting module, several modules may be combined to form a lighting assembly. Such an assembly of modules may be driven in several different ways.

[0010] Obviously, the modules 2 can all be individually driven. The topology is given in figure 6; each module 2 of the assembly 10 is connected to its own driver 3. This again is the most complex and expensive arrangement.

[0011] Alternatively, the modules 2 can be connected in series and driven as a single string 11 of N modules 2 (Fig. 7). This results in a setup where a (fluctuating) system voltage from a constant current source offers the lowest possible system voltage combined with an equal current distribution per LED. The performance parameter Lumen/Watt on system level is highest in this configuration.

[0012] It is also conceivable for the modules 2 to be connected both in series and in parallel. This results in a matrix 12 of modules 2, which all share a common driver 3. The driver 3 can be either a constant current source (Fig. 8) or a constant voltage source (Fig. 9). The resulting setup has a constant system voltage over N LED modules 2 in series.

[0013] As the LEDs are never exactly the same on a production batch - they will exhibit a relatively large spread in forward voltage and a relatively small spread in dynamic resistance - the current injected into a module will not spread evenly into all the branches of the module. Some branches will carry less current, while necessarily others will have current exceeding the maximum allowed current rating. This applies to all configuration having the general layout as shown in Figures 3, 4 and 5. And since the various modules will not have identical or even at least similar properties, they can only be connected in parallel by means of trimming electronics interconnected between the modules.

[0014] A number of potential solutions has been proposed to overcome these problems, like e.g. "binning", the use of adaptive current sources or the use of current limiting resistors. However, each of these solutions has major disadvantages in performance. Nor do these solutions lead to sufficiently identical operating conditions for each LED to offer a long lifetime and a high reliability over the lifetime. For instance "binning", i.e. selecting LEDs having properties - like e.g. light output flux or forward voltage at reference conditions - within narrowly defined boundaries, is a very efficient option for a designer. However, narrow "binning" on either of these parameters is usually not available, or only at substantially higher costs, which may render the whole system too expensive for commercial application. On the other hand, the high loss in all current limiting devices is clearly a problem when a designer wants to achieve very high efficiency on the system level, with efficiency being defined as the ratio of net light output (in Lumen) to energy input (in Watt) on a module level.

[0015] Therefore, there is a clear need for an improved way of arranging LEDs in a lighting module.

Summary of the invention

[0016] To meet this need, the invention provides a lighting module comprising a plurality of light emitting diodes (LEDs) connected in a circuit comprising a plurality of parallel strings, each said string including at least one LED, wherein at least one trimming element is connected in series with each said string, and wherein a characteristic value of at least some of the trimming elements is individually adjustable to control a current and/or a voltage in the corresponding string. By suitable adjustment of the characteristic value of the various trimming elements, differences between the individual strings may be minimised and a more uniform lighting may be achieved.

[0017] Preferred embodiments of the lighting module of the invention form the subject matter of dependent claims 2-5.

[0018] The invention further provides a lighting assembly comprising a plurality of mutually connected lighting modules of the type described above. A preferred embodiment of this lighting assembly is defined in dependent claim 7.

[0019] In accordance with another aspect of the invention, there is provided a method of individually adjusting a plurality of trimming elements, each of which is connected in series with one of a plurality of mutually connected parallel strings of LEDs, comprising the steps of:

a) applying a predetermined voltage to the parallel strings of LEDs,
b) identifying the string of LEDs for which a selected parameter has an optimum value, and
c) individually adjusting at least some of the trimming elements in the other strings until the selected parameter in each string of LEDs has a value which is substantially equal to the optimum value.

[0020] Preferred ways of carrying out this method form the subject matter of dependent claims 9-12.

[0021] The invention further provides a method of forming a lighting module, comprising the steps of:

- providing a plurality of light emitting diodes (LEDs) having characteristics which may vary from one LED to another,
- connecting the LEDs in a circuit comprising a plurality of parallel strings, each said string including at least one LED,
- connecting at least one trimming element in series with each said string, and
- individually adjusting a characteristic value of at least some of the trimming elements to control a current and/or a voltage and/or a net light output in the corresponding string.

[0022] The use of trimming elements allows the module to be formed from LEDs which may have a relatively large spread in their characteristics. Such LEDs can be obtained at relatively lower cost than LEDs having a smaller spread. Variants of this method are defined in dependent claim 14.

[0023] And finally, the invention provides a method of forming a lighting assembly, comprising the steps of providing a plurality of lighting modules formed by the method described above, and mutually connecting these lighting modules.

[0024] According to an aspect of the invention, light generating sources, each including at least one light emitting diode, are connected in a parallel way, with a trimming element in each string. The trimming elements intrinsic primary value is modulated by a trimming method, such that a selected design parameter correctly falls within a required range. In an illustrated example, the currents in a plurality of parallel LED strings fed by a single current source are adjusted by means of trimming resistors. Resistance values of the trimming resistors may be individually adjusted so that the voltage drop generated by each trimming resistor induces an equal current flow in each string, or induces a constant light output flux per string. This in turn leads to more uniform heat distribution, which will eventually result in a longer lifetime and a more reliable operation of module based on parallel LED strings. Thus, the invention provides a method of active trimming that offers the highest possible efficiency on a system level in combination with an identical current per LED that is needed for a long lifetime and a high reliability.

[0025] The invention is based on the configuration shown in Fig. 10 and adds the function of active trimming to a resistive stabilizer element for each parallel string of LEDs. It allows the number of parallel strings to be very high - 10 parallel segments and more are possible - while maintaining the DC current per string within a very accurate and controllable design range. As a result, the voltage level per string can be kept sufficiently low, while any desired module output performance with a multiple string configuration can be designed for reliable operation.

[0026] On a module level, the invention makes it possible to equalize each module's resistive performance by trimming in a constant voltage/current relation. As a result a system designer can build a light source of any configuration of parallel and serially placed modules as shown in figures 8 and 9 without the need for any additional trimming electronics.

[0027] The aim of the invention is to achieve a reproducible constant narrow spread in current between different LED strings in a parallel arrangement. The resistive elements that are added in series with the strings are trimmed to such a level that each imbalance in current per string due to LED process spread variation is compensated for, while at the same time no additional performance loss occurs on a module level. In other words, only those strings are trimmed which need "adaptation" with the designed spread; strings with a current that is already fitting within the designed spread are not modified by trimming.

[0028] By individually adjusting the value of the trimming elements, a main design parameter may be kept within the design bounds. This main design parameter can be any parameter, depending on the design of the system. Suitable design parameters include process parameters like constant module voltage, equal current per LED string, constant LED string flux output, constant color consistency and other process parameters directly related to light emitting diodes. This list is not exhaustive, but just serves as illustration of the principle.

[0029] Alternatively, trimming the value of the trimming element may result in the current through each LED string being substantially equal to the current through the other strings, while at the same time maintaining the highest possible value for performance parameter like Lumen per Watt (per module), small tolerance constant module voltage, minimum color consistency spread or small tolerance constant current per string and per LED. Again, this list is not exhaustive.

[0030] In similar fashion, the module of trimmed LEDs allows arbitrary constant current and constant voltage driver configurations of multiple LED modules with a design objective of either best Lumen/Watt performance per module; equal current distribution per set of parallel modules; equal light flux output of parallel and/or series connected modules; equal narrow banded color correlation performance of parallel and/or series connected modules, or other design objectives.

Brief description of the drawings

[0031] The invention will now be elucidated on the basis of an exemplary embodiment thereof. Reference is made to the annexed drawings, in which like elements are identified by the same reference numerals, and in which:

Fig. 1 is a schematic representation of a conventional arrangement in which each LED is individually driven,
Fig. 2 schematically shows a conventional signal LED string configuration;
Fig. 3 is a schematic of a conventional arrangement of parallel LED strings;
Fig. 4 illustrates a conventional configuration of parallel LED strings forming a matrix;
Fig. 5 schematically shows a prior art parallel LED string with stability resistor in series;
Fig. 6 is a schematic illustration of an assembly of individually driven LED modules;
Fig. 7 schematically shows a series connection of a plurality of LED modules;
Fig. 8 is a schematic representation of a plurality of LED modules arranged in series and in parallel to form a matrix having a constant current source;
Fig. 9 is similar to Fig. 8, but shows a constant voltage source;
Fig. 10 schematically illustrates a module including parallel LED strings in active trimming configuration in accordance with the invention;
Fig. 11 shows an actual embodiment of an elongated module in accordance with the invention, which includes 18 LEDs;
Fig. 12 is a schematic representation of the LED module of Fig. 11, and
Fig. 13 illustrates a model representing the LED module of Figs. 11 and 12 for use in determining the trimming values.

Detailed description

[0032] An LED module 10 in accordance with the invention comprises a plurality of LED strings 4 (Fig. 10). Each string 4 includes one or more LEDs 1 and a trimmable device 13, 13', ..., 13^k connected in series with the negative end 6 of the string 4. In the illustrated embodiment, the trimmable device 13 is a suitable resistor element. In a preferred embodiment, the trimmable device 13 is a surface mounted device chip resistor, either thick film or thin film, which may be trimmed using a laser trimming machine.

[0033] In an actual embodiment of the invention as shown in Fig. 11, the module 10 includes 18 LEDs 1, which are arranged in six parallel strings 4 of three LEDs

1 each. The module 10 is shaped as a strip-like PCB 14, with all LEDs 1 evenly spaced in a row on the centerline of the strip 14. Each LED string 4 is provided with a trimming resistor 13, which is connected in series with the string 4. In the actual embodiment these resistors 13 are arranged between the LEDs 1 of their corresponding string 4. The module 10 further includes a positive terminal 15, which may be connected to a driver (not shown here) and a negative terminal 16, which may be connected to earth. The negative terminal 16 might also be connected to another module 10, resulting in an arrangement of the type shown in Figs. 8 and 9. In the actual embodiment, the terminals 15, 16 are arranged near opposite ends of the strip-like PCB 14.

[0034] The module 10 of Fig. 11 is schematically illustrated in Fig. 12. In that representation various pairs of test points 17, 18 are shown, which correspond with each pair of strings 4. The test points 17A are each arranged on a first collective line or positive line 19 connecting the strings 4 with the positive terminal 15. The test points 17B are arranged on a second collective line or earth line 20 connecting the strings 4 with the negative terminal 16. Each test point 17A, 17B is arranged halfway between two adjacent LED strings 4. Each test point 18A, 18B is arranged in one of the strings 4, between the LEDs 1 and the trimming resistor 13. In the actual embodiment of the module 10, the test points 17, 18 are arranged between and in line with the LEDs 1.

[0035] Finally, an additional diode 21 is arranged in a short circuit line between the two collective lines 19, 20, in order to avoid damage to the circuitry in case of an incorrect polarity connection of the terminals 15, 16. Before calibration, each resistor 13 has a low value, e.g. in the order of 0.5 - 1.0 Ohm. The low value is not fixed, but is selected so that the voltage drop in the resistors 13 is acceptable from a design point of view (low power dissipation), while still providing a necessary minimum voltage drop and resistive trimming range for environmental drift in LED characteristics.

[0036] During the trimming procedure, each LED string 4 is fed with the nominal designed current, and the diode stack voltages of all LEDs 1 in series in the string 4 are measured. This measurement can either be a progressive process, with strings 4 being measured one after the other, or a parallel process of multiple strings 4 and modules 10 in parallel.

[0037] In the embodiment of Figs. 11 and 12, two measurements are performed virtually concurrently for each pair of strings 4. One of the measurements is between the test points 17A and 17B, and measures the voltage over the two strings 4 in their entirety, including the LEDs 1 and the resistor 13, and also including parts of the collective lines 19 and 20. The other measurement is between test points 18A and 18B. This measures the voltage over the two trimming resistors 13 of the two strings 4 and the part of the collective earth line 20 there between.

[0038] These measurements are explained by reference to the model shown in Fig. 13. When looking at the left hand part of the circuit that is shown there, diodes D1 and D2 represent the three LEDs 1 in each of the first two strings 4. Resistances R1, R2 and R3 represent the (small) resistance of the collective line 19 between the positive terminal 15 and the first string 4, between the first string 4 and the test point 17A, and between the test point 17A and the second string 4', respectively. Resistances R6 and R7 represent the resistance in the strings 4 between the connection with the positive line 19 and the test points 18A, 18B, respectively. Resistances R9 and R15 represent the nominal resistance values of the trimming resistors 13, 13', respectively, while resistances R8 and R10 represent the trimming value that is needed to equalize the current in the two strings 4, 4'. And finally, resistances R11 and R12 represent the resistance of the part of the strings 4, 4' and the earth line 20 between each of the test points 18A, 18B and the test point 17B, respectively.

[0039] Using this model, measurements between the two pairs of test points 17A, 17B and 18A, 18B, respectively, allow all values of the resistances to be determined. In particular, these measurements allow the necessary amount of trimming to be calculated.

[0040] Once all the strings 4 on a module 10 have been measured, the highest string voltage caused by the specific characteristics of all LEDs 1 mounted on that module 10 is calculated, as is the minimum voltage drop through the trimming elements 13. In that way the optimum module performance is known. At optimum module performance at least one of the trimming resistors 13 is NOT trimmed but represents the dominant string 4 that defines the total module performance. Subsequently all other strings 4 connected in parallel are trimmed in such a way that they match the dominant string - having the highest accumulated forward voltage over the LEDs 1 - within the required accuracy bandwidth. This is done by trimming each resistor 13 in a non-dominant string 4 to a higher value and thus increasing the voltage over the trimming resistor 13 of that string 4. The remaining total voltage V_{string} on each module 10 represents the best possible module performance for the parameter Lumen per Watt. The actual accumulated light flux output levels per string may vary from string to string in this configuration.

[0041] In another embodiment, where a constant output of light is desired as parameter for equality, the trimming process is equivalent to the process described above. However, in this case the trimming occurs in a way that the total light output flux per LED string 4 is trimmed such that it matches the dominant string - in this case the string 4 having the minimum light flux output - within the necessary accuracy bandwidth. Again, each resistor 13 in a non-dominant string 4 is trimmed to a higher value, thus increasing the voltage over the trimming resistor 13 of that string and reducing the current per LED 1. In that way the generated light output flux of each string 4 is reduced to a level that is equal to that of the dominant string 4. The resulting module voltage at intended current source causes a constant light flux output per string, while the actual currents per string may vary in this configuration.

[0042] An important aspect of the invention is that the trimming element that is connected to the string having the highest voltage or lowest flux output is not trimmed at all - to obtain the lowest possible string arrangement voltage - or trimmed to a predetermined and relatively low value.

[0043] In the preferred embodiment the resistor 13 that is connected to the string 4 having the highest voltage is left untrimmed, so it maintains its default and minimal value. The trimming resistors 13 connected to the other strings 4 are individually adjusted so that the current going through each string 4 is sufficiently close to the current going through the string 4 with the highest forward voltage drop - the dominant string. The matching of the current through all strings is a design choice, which is only limited by technical choices of the designer.

[0044] Using this invention, any process parameter linked to the current flowing through the LED strings 4 can be adjusted. For example, the light output of two LED strings made of LEDs with different Correlated Colour Temperature (CCT) can be adjusted so that the light having a CCT in between the original CCTs can be produced by proper mixing.

[0045] Alternatively, LEDs with a bigger than normal spread in one of the process parameters, such as output flux or forward voltage or color consistency, can still be used - even without factory binning - to create reliable LED modules. To this end a higher trimming range has to accepted in the resistor value, as well as a wider spread in essential LED characteristics.

[0046] Using the arrangements and methods of the invention, LED engines of any configuration with very good control of the current flowing in each string and with very low power loss can be manufactured.

[0047] Although the invention has been illustrated by means of an exemplary embodiment, it is not limited thereto, but may be adapted and varied in many ways. For instance, it is conceivable that more than one trimming element is arranged in each string, e.g. when the rating of the trimming element is insufficient to accommodate the maximum adjustment that is required. Moreover, it is not strictly necessary to arrange the trimming element at an extremity of a string; it could also be arranged between two LEDs in the string, if this would be preferable with a view to the equipment used for measuring and trimming. Consequently, the scope of the invention is defined solely by the appended claims.

Claims

1. A lighting module comprising a plurality of light emitting diodes (LEDs) connected in a circuit comprising a plurality of parallel strings, each said string including at least one LED, wherein at least one trimming element is connected in series with each said string, and wherein a characteristic value of at least some of the trimming elements is individually adjustable to control a current and/or a voltage in the corresponding string.

2. The lighting module as claimed in claim 1, wherein the characteristic value of the trimming elements is upwardly or downwardly adjustable.

3. The lighting module of claim 1 or 2, wherein the characteristic value of the trimming elements is individually adjustable so that:

   - a main design parameter of the circuit is maintained within predetermined design bounds, or
   - the current and/or lumen light output in all strings is substantially equal while a performance parameter of the module is maximized.

4. The lighting module as claimed in any of the preceding claims, wherein the trimming element is a trimmable resistor and the characteristic value is its resistance.

5. The lighting module as claimed in any of the preceding claims, wherein a reversely oriented diode is connected with its cathode to a positive input terminal and with its anode to a negative input terminal of the module, and preferably further comprising at least one current limiting element and/or reverse voltage element and/or overvoltage protection element.

6. A lighting assembly comprising a plurality of mutually connected lighting modules as claimed in any of the preceding claims.

7. The lighting assembly as claimed in claim 6, wherein at least some of the lighting modules are connected in series, and/or wherein one or more of the lighting modules are connected in parallel.

8. A method of individually adjusting a plurality of trimming elements, each of which is connected in series with one of a plurality of mutually connected parallel strings of LEDs, comprising the steps of:

   a) applying a predetermined voltage to the parallel strings of LEDs,
   b) identifying the string of LEDs for which a selected parameter has an optimum value, and
   c) individually adjusting at least some of the trimming elements in the other strings until the selected parameter in each string of LEDs has a value which is substantially equal to the optimum value.

9. The method as claimed in claim 8, wherein:

- the selected parameter is a maximum voltage;
- the string having the highest voltage is identified by measuring a current flowing through each string and comparing the measured current values, and
- the resistance of at least some of the trimming elements in the other strings is individually increased.

10. The method of claim 9, wherein measurements are performed on two adjacent strings substantially concurrently, and wherein preferably two measurements are performed for each pair of adjacent strings, each of the measurements covering a different part of each string.

11. The method as claimed in any of claims 8-10, wherein the properties of each string of LEDs are set such as to be maintained within predetermined boundaries over their lifetime, and wherein preferably the trimming elements are individually adjusted by laser trimming.

12. The method as claimed in any of claims 8-11, wherein step c) includes individually adjusting at least some of the trimming elements in the other strings until a current or voltage or net light output performance parameter has a substantially equal value in each string.

13. A method of forming a lighting module, comprising the steps of:

- providing a plurality of light emitting diodes (LEDs) having characteristics which may vary from one LED to another,
- connecting the LEDs in a circuit comprising a plurality of parallel strings, each said string including at least one LED,
- connecting at least one trimming element in series with each said string, and
- individually adjusting a characteristic value of at least some of the trimming elements to control a current and/or a voltage and/or a net light output in the corresponding string.

14. The method as claimed in claim 13, wherein the characteristic value of the trimming elements is individually adjusted so that a main design parameter of the circuit is maintained within predetermined design bounds, and wherein preferably the characteristic value of the trimming element is individually adjusted so that the current in all strings is substantially equal while a performance parameter of the module is maximized.

15. A method of forming a lighting assembly, comprising the steps of:

- providing a plurality of lighting modules formed by the method as claimed in any one of claims 18-20, and
- mutually connecting these lighting modules, wherein preferably at least the two or more lighting modules are either connected in series or in parallel or in a arbitrary mixture of parallel and serial connections.

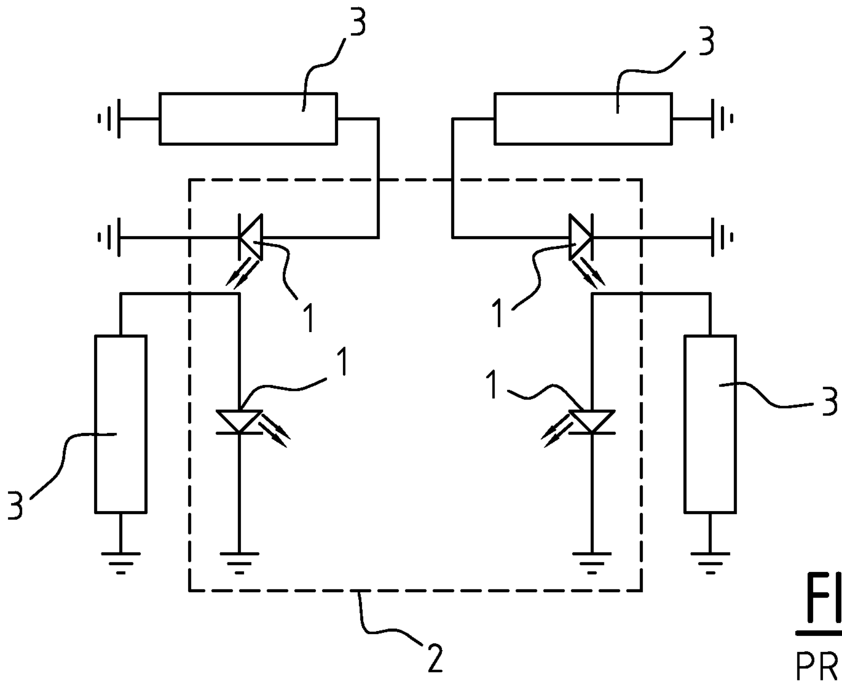

FIG. 1
PRIOR ART

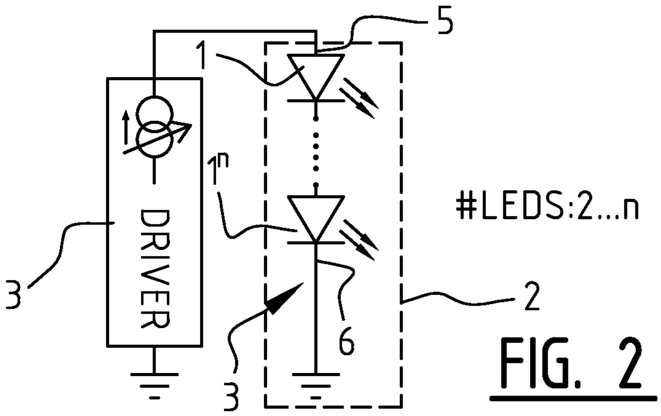

FIG. 2
PRIOR ART

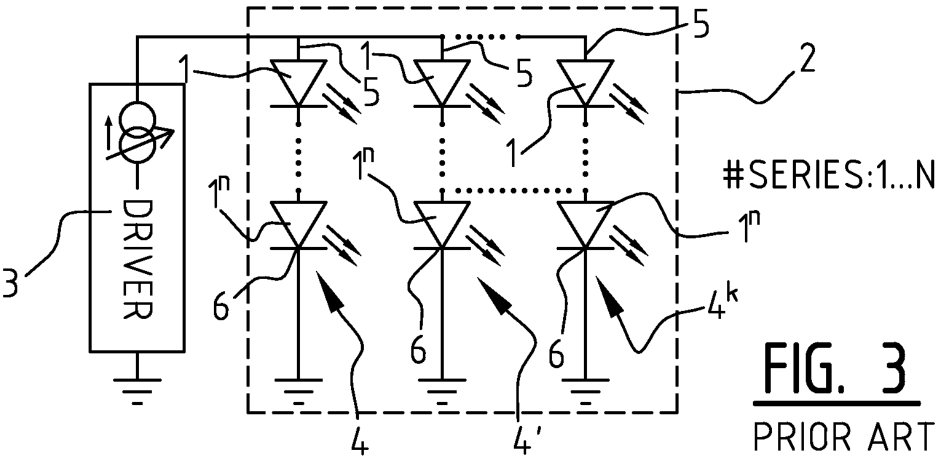

FIG. 3
PRIOR ART

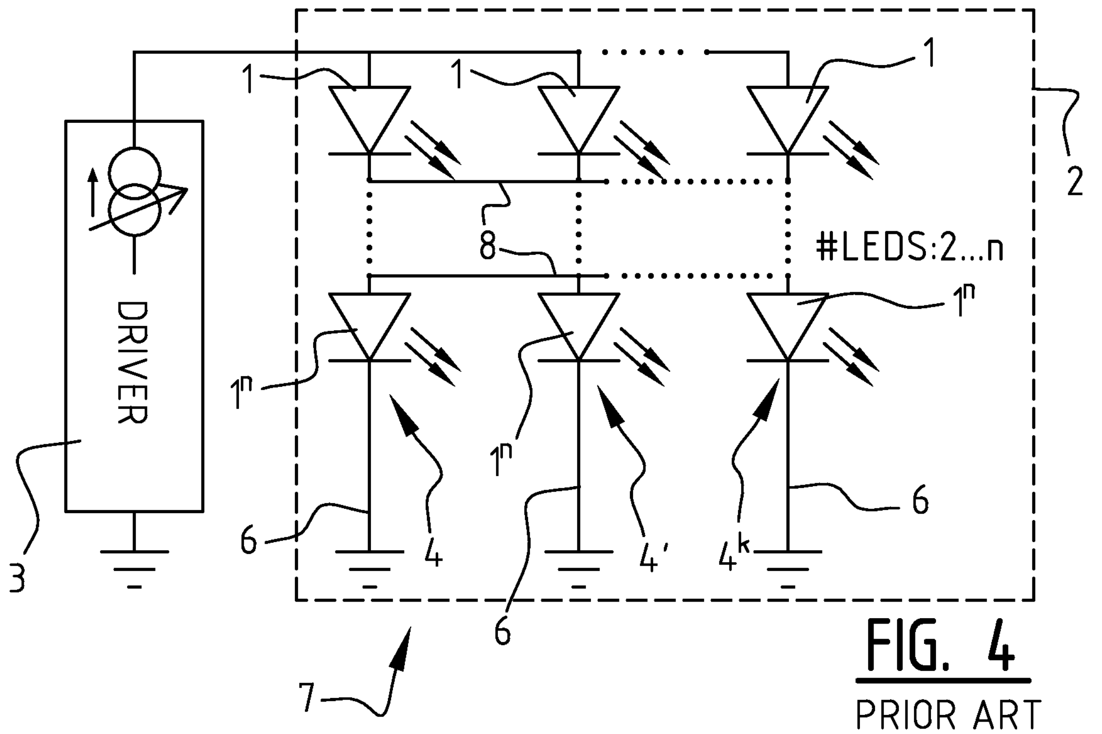

FIG. 4
PRIOR ART

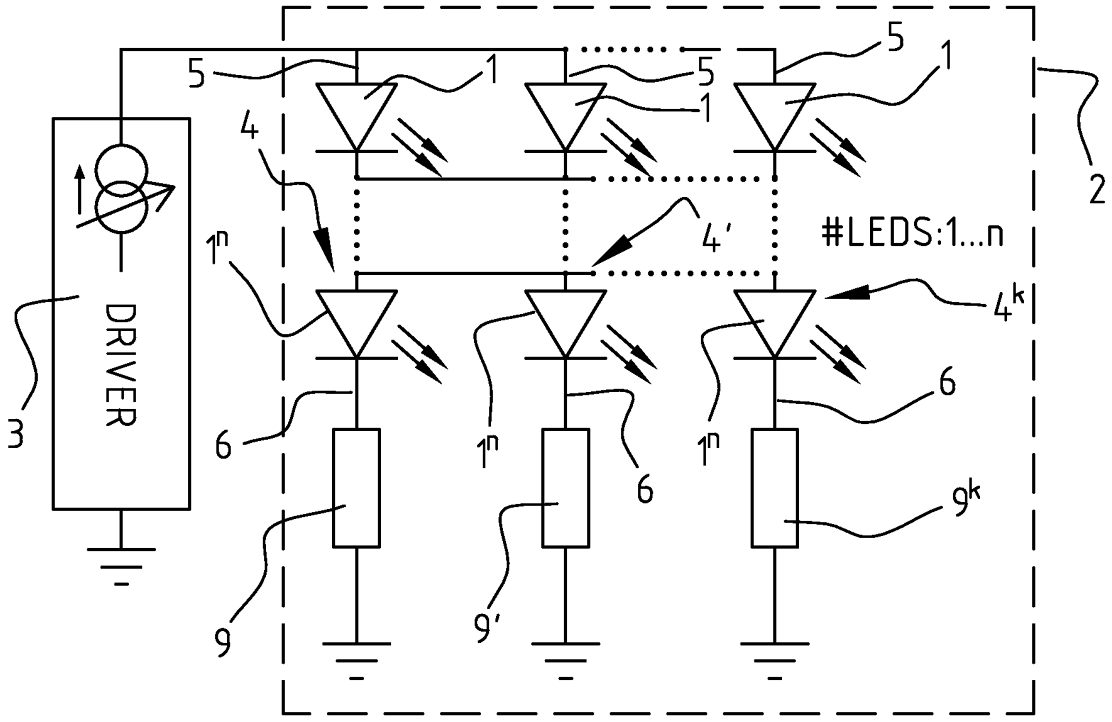

FIG. 5
PRIOR ART

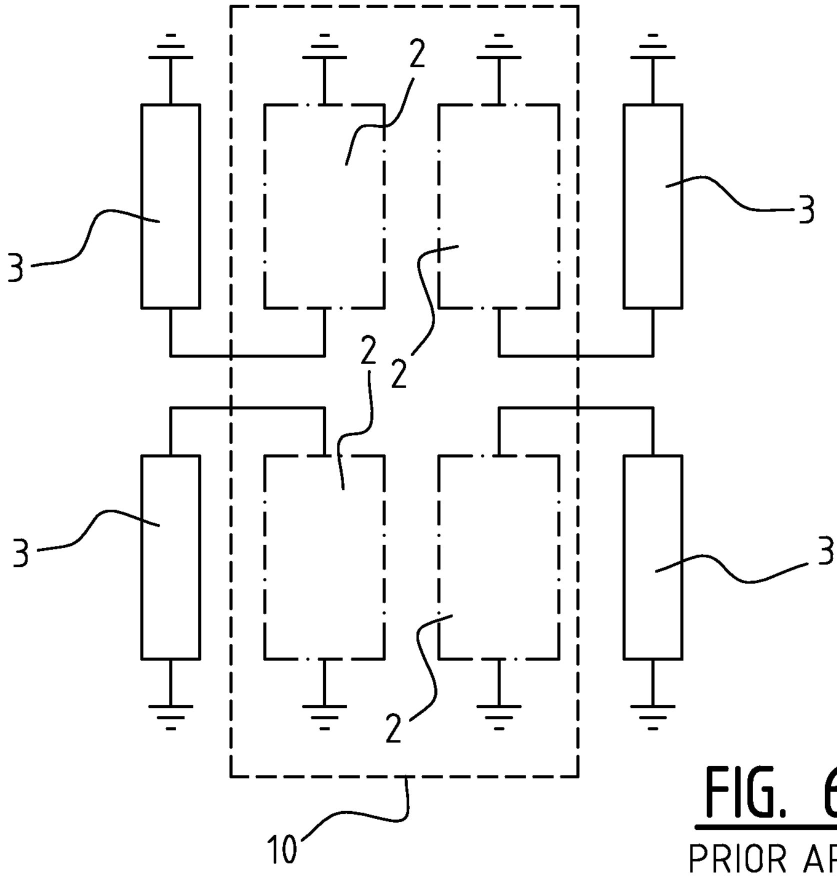

FIG. 6
PRIOR ART

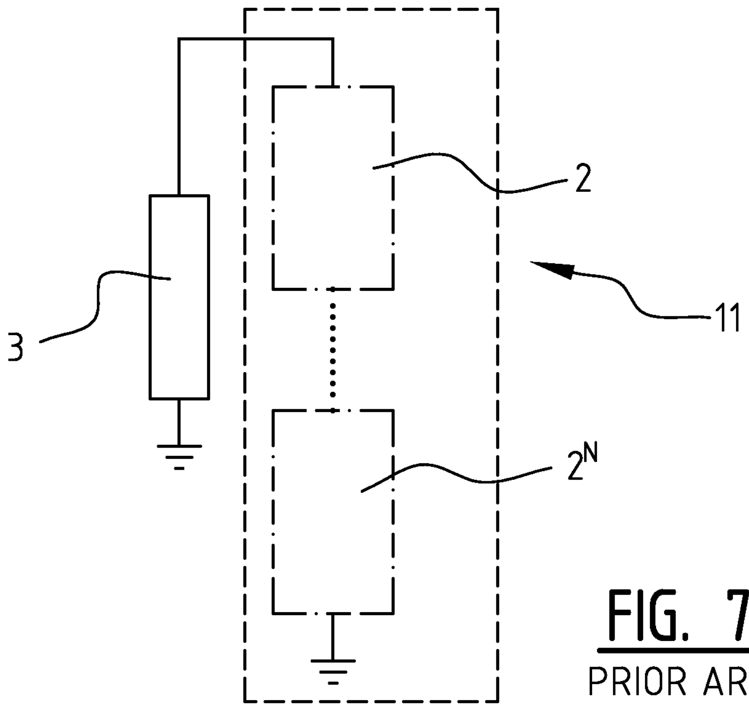

FIG. 7
PRIOR ART

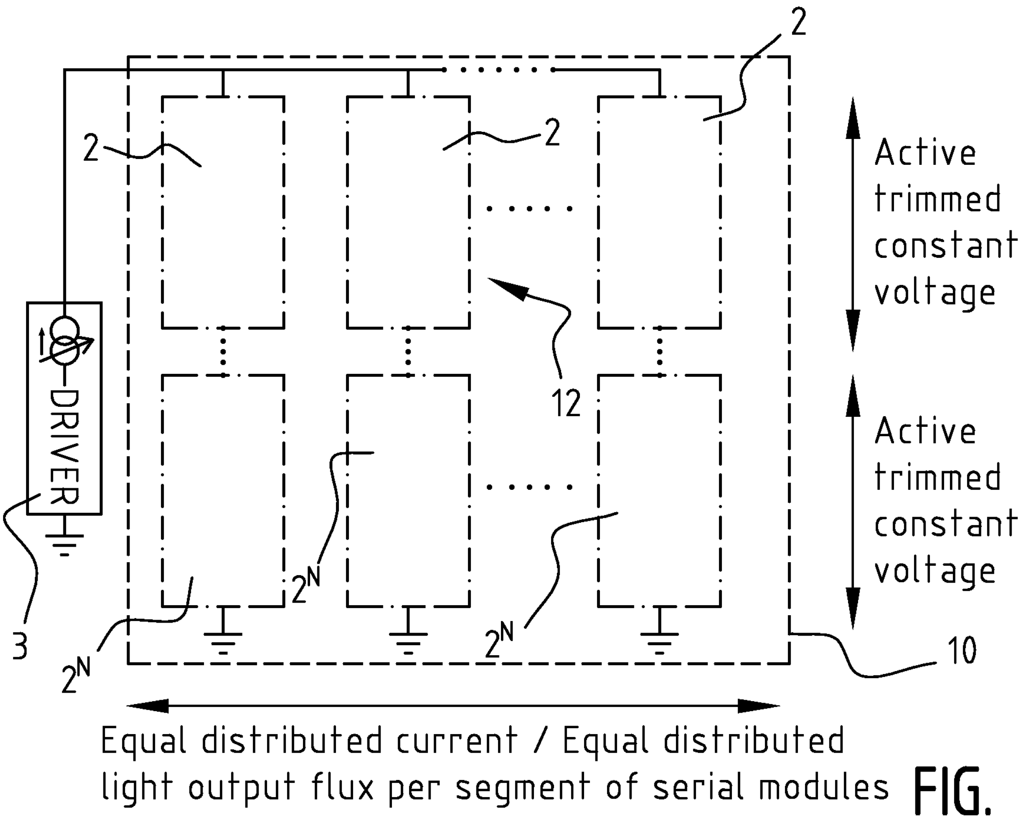
2
2
2
DRIVER
3
12
2^N
2^N
2^N
10
Active trimmed constant voltage
Active trimmed constant voltage
Equal distributed current / Equal distributed light output flux per segment of serial modules

FIG. 8

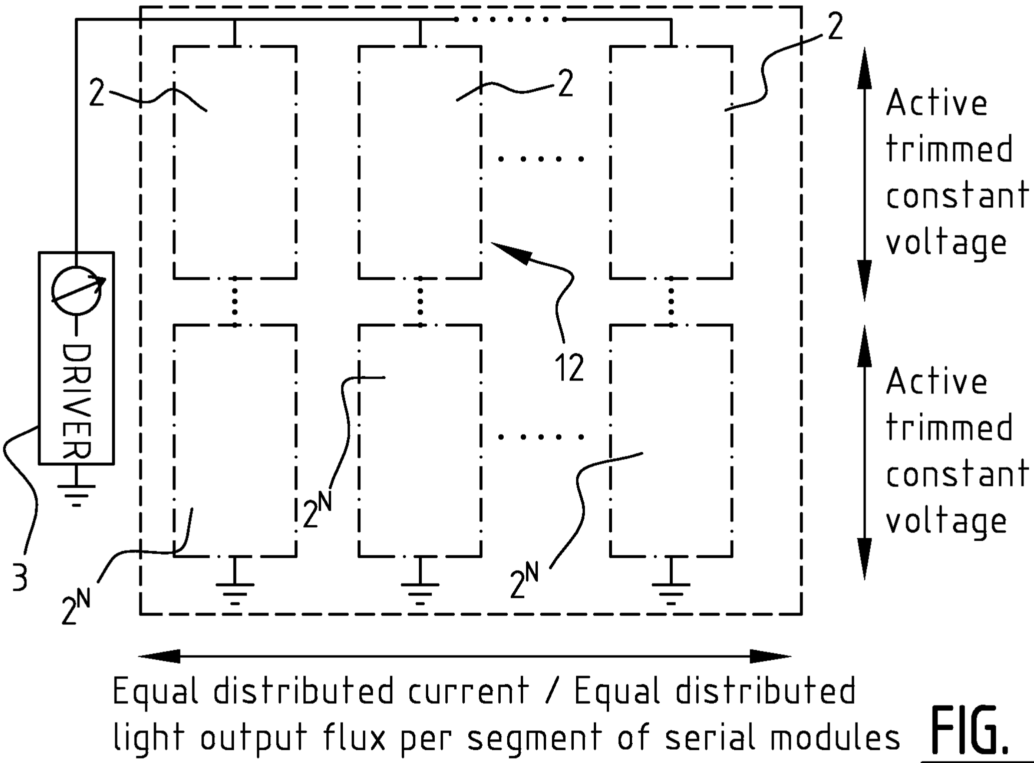
2
2
2
DRIVER
3
12
2^N
2^N
2^N
Active trimmed constant voltage
Active trimmed constant voltage
Equal distributed current / Equal distributed light output flux per segment of serial modules

FIG. 9

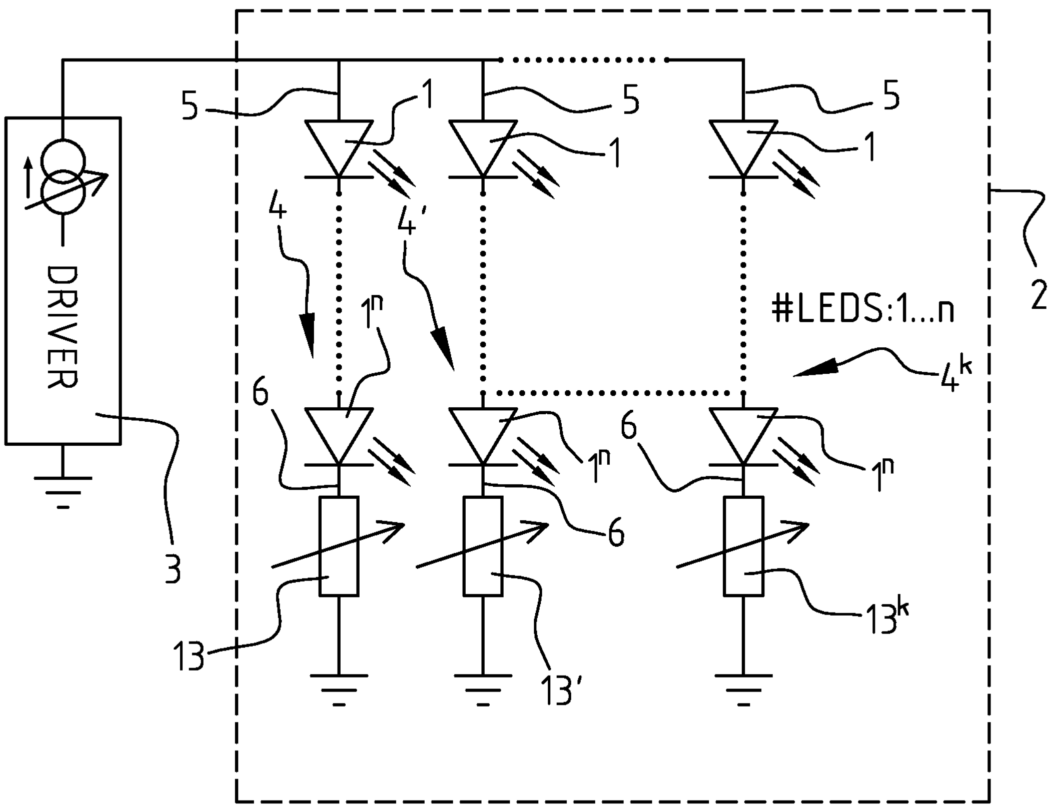

FIG. 10

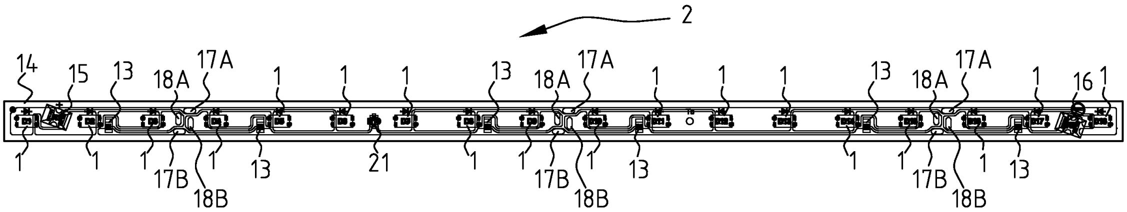
2
14
15
13
18A
17A
1
16
17B
18B
21

FIG. 11

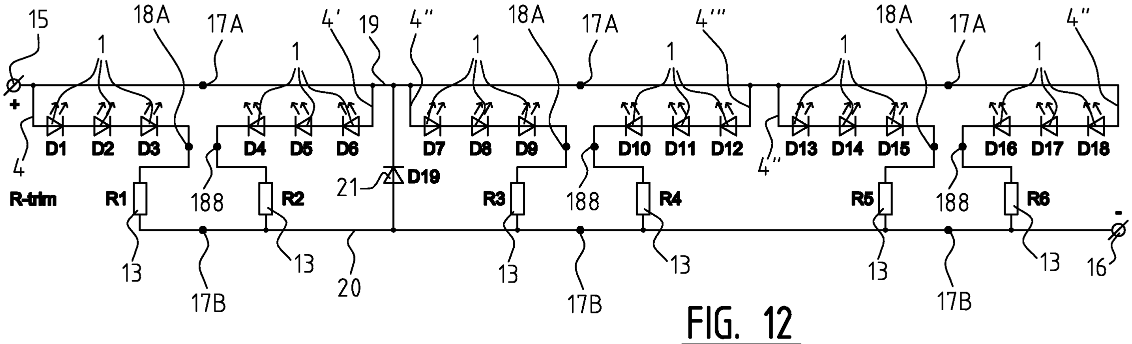
15
18A
17A
4'
19
4"
4'"
1
+
4
D1
D2
D3
D4
D5
D6
D7
D8
D9
D10
D11
D12
D13
D14
D15
D16
D17
D18
D19
21
R-trim
R1
R2
R3
R4
R5
R6
188
13
17B
20
16
-

FIG. 12

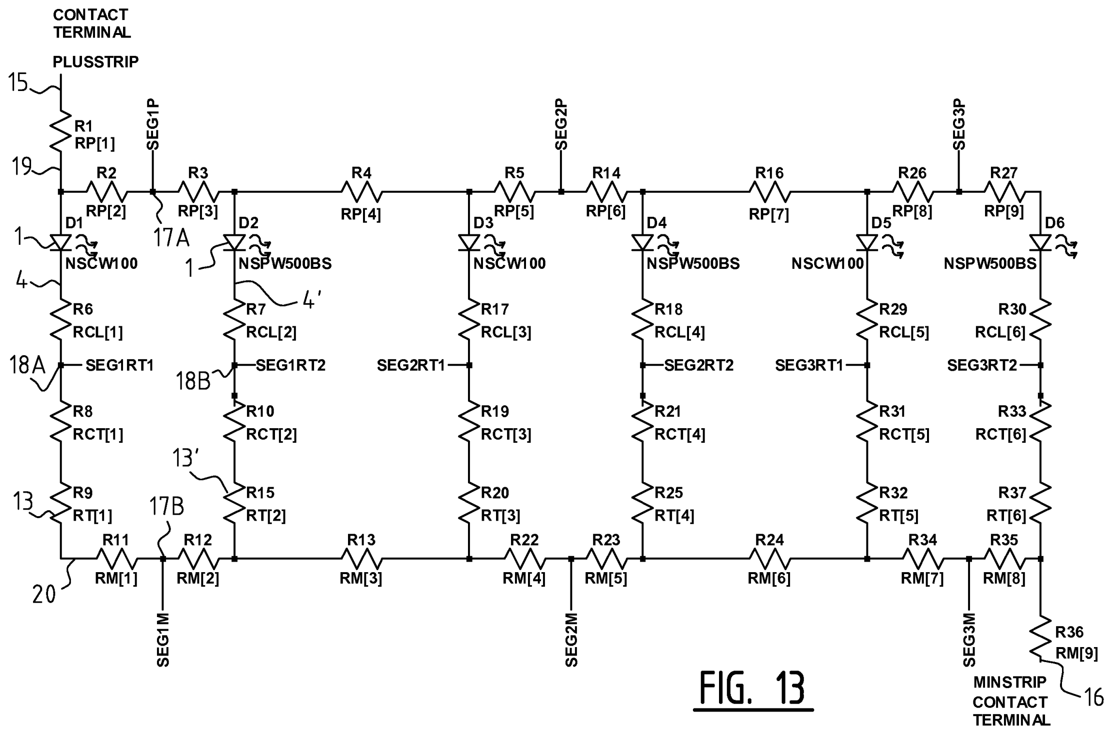
CONTACT
TERMINAL
PLUSSTRIP
15
19
1
4
18A
13
20
17A
17B
1
4'
18B
13'
R1
RP[1]
SEG1P
SEG2P
SEG3P
R2
RP[2]
R3
RP[3]
R4
RP[4]
R5
RP[5]
R14
RP[6]
R16
RP[7]
R26
RP[8]
R27
RP[9]
D1
NSCW100
D2
NSPW500BS
D3
NSCW100
D4
NSPW500BS
D5
NSCW100
D6
NSPW500BS
R6
RCL[1]
R7
RCL[2]
R17
RCL[3]
R18
RCL[4]
R29
RCL[5]
R30
RCL[6]
SEG1RT1
SEG1RT2
SEG2RT1
SEG2RT2
SEG3RT1
SEG3RT2
R8
RCT[1]
R10
RCT[2]
R19
RCT[3]
R21
RCT[4]
R31
RCT[5]
R33
RCT[6]
R9
RT[1]
R15
RT[2]
R20
RT[3]
R25
RT[4]
R32
RT[5]
R37
RT[6]
R11
RM[1]
R12
RM[2]
R13
RM[3]
R22
RM[4]
R23
RM[5]
R24
RM[6]
R34
RM[7]
R35
RM[8]
R36
RM[9]
SEG1M
SEG2M
SEG3M
MINSTRIP
CONTACT
TERMINAL
16

FIG. 13