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(54) A AUTOMOTIVE LIGHTING UNIT AND OPERATION METHOD THEREOF

(57) A automotive lighting unit (1) comprising a lighting device (4) provided with an emissive LED display (5) consisting of multiple LED arrays (7) arranged so as to form the rows or columns of an LED matrix, and a control driver (11) configured in order to: receive an image frame (F1) containing multiple data arrays (D(i)) that codify the light image to be be displayed during a refresh interval (TR) via corresponding LED arrays (7) of the LED display (5), process the image frame (F1) to determine the data arrays (D(i)) that codify a first operating condition of first LED arrays (D(i)) in the LED display (5), determine the activation intervals (TA) based on the refresh interval (TR) and the data arrays (D(i)) of the image frame (F1) meeting the first operating condition, during the refresh interval (TR), control the sequential and selective activation, one after the other, of the first LED arrays (7) based on the activation intervals (TA) determined, and prevent the remaining LED arrays (7) from being activated.

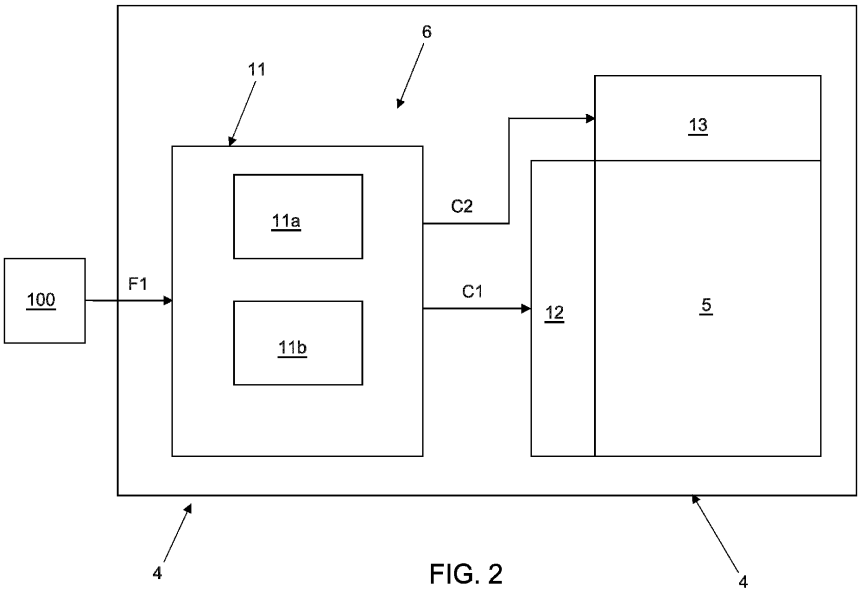


FIG. 2

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Description

TECHNICAL FIELD

[0001] This invention concerns an automotive lighting unit provided with a lighting source comprising at least one LED display and the operation method thereof.

[0002] This invention preferably concerns an automotive lighting unit which is provided with an electronic lighting circuit provided with: at least one LED matrix display preferably based on a mini-LED architecture, and an electric/electronic control device, which is configured to control the LED matrix display, conveniently according to the control method described in detail below.

[0003] More specifically, this invention relates to a automotive head light and/or an automotive tail light and/or an automotive side light for vehicles or motor vehicles or similar vehicles with motors, of the kind preferably comprising: a shell structured so it can be enclosed inside a compartment formed on the body of the vehicle, a front lenticular body at least partially made of transparent or semi-transparent material that can be coupled to the shell at the mouth of the same, a lighting device that is designed to be arranged inside the shell and comprises, in turn, an electronic lighting circuit provided with at least one LED display, and an electronic control device, which is configured so as to control the LED display, preferably using PWM (Pulse Width Modulation) signals.

[0004] In the latest-generation automotive lighting units, the widespread use of electronic technology involving the use of LED light sources is known. This widespread use is essentially due to the fact that the LED light sources make it possible to obtain multiple and different lighting effects, both static and dynamic, and are particularly versatile and adaptable since they make it possible to perform any lighting function required in a vehicle.

[0005] However, although the above-mentioned automotive lighting units with LED light sources allows to obtain the advantages described above, there is a strong need to additionally increase the performance of the automotive lighting unit, and, in particular, to increase both the complexity and dynamic nature of the images generated using the automotive lighting unit, but without affecting, at the same time, the complexity of the existing electronic control systems, in particular the control drivers, especially PWM control drivers, and the production costs of the same.

DESCRIPTION OF THE INVENTION

[0006] The purpose of this invention is, therefore, that of providing an automotive lighting unit equipped with an LED light source and an operation method for the automotive lighting unit that are able to meet at least the above-mentioned requirement.

[0007] This purpose is achieved with this invention in that it relates to an automotive lighting unit comprising: a lighting device provided with an emissive LED display consisting of multiple LED arrays arranged so as to form the rows or columns of an LED matrix, comprising a control driver that is configured in order to: receive an image frame containing multiple data arrays that codify the light image to be displayed during a refresh interval via corresponding LED arrays of said LED display; process the image frame to determine the data arrays in said image frame that codify a first operating condition of first LED arrays in said LED display; determine the activation intervals based on said refresh interval and the data arrays of said image frame which satisfy said first operating condition, during said refresh interval; control the sequential and selective activation, one after the other, of said first LED arrays based on the activation intervals determined, and prevent the remaining LED arrays from being activated.

[0008] The first operating condition is preferably a switched-on condition for said first LED arrays of said LED display wherein first LED arrays have one or more LEDs switched on.

[0009] Said control driver is preferably configured to increase the activation intervals of said first LED arrays, in inverse proportion to the number of data arrays that codify said switched-on state.

[0010] The first operating condition is preferably a switched-off condition for said first LED arrays of said LED display wherein first LED arrays have all the LEDs switched off.

[0011] The control driver is preferably configured to increase the activation intervals of said first LED arrays, in inverse proportion to the number of data arrays that codify said switched-off state.

[0012] The control driver is preferably configured in order to: determine the number of data arrays in the image frame that codify said first operating condition, and determine the activation times based on said number of data arrays and of said refresh interval.

[0013] The control driver is preferably configured in order to generate first PWM command signals to selectively activate, one after the other, said LED arrays of said LED display, said control driver also being configured to vary the duty cycle of said first PWM command signals based on determined activation times.

[0014] The data array of said images frame preferably comprise LED values that are associated with the light intensities to be generated via the LEDs of said LED arrays, said control driver is also configured in order to: calculate a first value containing the sum of said LED values of said image frame, compare said first value with an intensity threshold, modify

the LED values of the data arrays that codify the switched-on state based on said comparison, maintain the LED values of the data arrays that codify the switched-off state.

[0015] The control driver is also preferably configured in order to increase the LED values in the data arrays that codify the switched-on state, when the first value is less than said intensity threshold.

[0016] The control driver is also preferably configured in order to compare the LED values in the data arrays that codify the switched-on state with a maximum LED intensity threshold and modify the LED values of the data arrays that codify the switched-off state when said LED values are greater than said maximum LED intensity threshold.

[0017] The LED display preferably comprises a mini-LED display. The mini-LED display is preferably passive matrix. The LED display preferably comprises a micro-LED display. The micro-LED display is passive matrix. The LED display preferably does not comprise any liquid crystal panel.

[0018] This invention also relates to an operation method for an automotive lighting unit comprising: a lighting device provided with an LED display consisting of multiple LED arrays arranged so as to form rows or columns of an LED matrix. The method comprises the steps of: receiving an image frame containing multiple data arrays that codify the luminous image to be displayed during a refresh interval by means of corresponding LED arrays of said LED display; processing the image frame to determine the data arrays in said image frame that codify a first operating condition of first LED arrays in said LED display; determining the activation intervals based on said refresh interval and the data arrays of said image frame which satisfy said first operating condition; during said refresh interval, controlling the sequential and selective activation, one after the other, of said first LED arrays based on the activation intervals determined; and preventing the remaining LED arrays from being activated.

[0019] The first operating condition is preferably a switched-on condition for said first LED arrays of said LED display wherein first LED arrays have one or more LEDs switched on.

[0020] The method preferably comprises the step of increasing the activation intervals of said first LED arrays, in inverse proportion to the number of data arrays that codify said switched-on state.

[0021] The first operating condition is preferably a switched-off condition for said first LED arrays of said LED display wherein first LED arrays have all the LEDs switched off.

[0022] The method preferably comprises the step of increasing the activation intervals of said first LED arrays, in inverse proportion to the number of data arrays that codify said switched-off state.

[0023] The method preferably comprises the steps of: determining the number of data arrays of the image frame that codify said first operating condition, and determining the activation times based on said number and said refresh interval.

[0024] The method preferably comprises the steps of: generating first PWM command signals to selectively activate, one after the other, said LED arrays of said LED display and varying the duty cycle of said first PWM command signals based on the determined activation times.

[0025] The data arrays of said images frame comprise LED values that are associated with the light intensities to be generated via the LEDs of said LED data arrays, said control driver is also configured in order to: calculate a first value containing the sum of said LED values of said image frame, compare said first value with an intensity threshold, modify the LED values of the data arrays that codify the switched-on state based on said comparison, maintain the LED values of the data arrays that codify the switched-off state.

[0026] The method preferably comprises the step of increasing the LED values in the data arrays that codify the switched-on state, when the first value is less than said intensity threshold.

[0027] The method preferably comprises the step of comparing the LED values in the data arrays that codify the switched-on state with a maximum LED intensity threshold and modify the LED values of the data arrays that codify the switched-off state when said LED values are greater than said maximum LED intensity threshold.

[0028] The claims describe preferred embodiments of this invention forming an integral part of this description.

BRIEF DESCRIPTION OF THE DRAWINGS

[0029] This invention will now be described with reference to the attached drawings that illustrate a non-limiting embodiment thereof, in which:

Figure 1 is an exploded view of an embodiment of an automotive lighting unit produced according to the precepts of this invention,

Figure 2 is a block circuit diagram of a preferred, example embodiment of a lighting device of the automotive lighting unit produced according to the precepts of this invention,

Figure 3 shows an image frame processed by the method for controlling an LED display of the automotive lighting unit produced according to this invention,

Figure 4 shows a circuit diagram of a passive matrix of a mini-LED display of the automotive lighting unit lighting device produced according to this invention,

Figure 5 is a flow chart of the operation method of the automotive lighting unit produced according to this invention,

Figures 6a, 6b, and 6c show other examples of automotive lighting units with LED displays produced according to this invention,

Figure 7 is a block circuit diagram of a different, example embodiment of a lighting device of the automotive lighting unit produced according to the precepts of this invention,

Figure 8 is a flow chart of the operation method of the automotive lighting unit produced according to the solution shown in Figure 7,

Figure 9 is a flow chart of the operation method of the automotive lighting unit produced according to this invention.

[0030] This invention will now be described in detail with reference to the figures attached to enable a person skilled in the art to produce it and use it. Various modifications to the embodiments described will be immediately clear to persons skilled in the art and the generic principles described may be applied to other embodiments and applications without, for this reason, departing from the protective scope of this invention, as defined in the attached claims. Therefore, this invention must not be considered as limited to the embodiments described and illustrated but they must be granted the widest protective scope compliant with the principles and features described and claimed herein.

[0031] With reference to Figure 1, the reference number 1 schematically illustrates, as a whole, an exploded view of an automotive lighting unit (also identified as "automotive headlight unit") that is the subject of this invention.

[0032] According to a preferred embodiment of this invention, the automotive lighting unit 1 may be, for example, an automotive tail light. It is, however, understood that this invention should not be considered as limited to the automotive tail light (car, truck, bus, or the like), but may be applied, in addition or alternatively, to an automotive headlight unit or automotive side light unit.

[0033] It is appropriate to specify in addition, that hereinafter the term "automotive lighting unit" 1 refers to a lighting device / piece of equipment that is designed to be included in a vehicle at the front or back and is designed to perform at least one or more of the following vehicle lighting functions: lighting the area around the vehicle, signalling its presence, signalling its position, signalling the direction in which the vehicle is moving. In other words, in the description that follows, the term "automotive lighting unit" will refer, optionally, to at least: a headlight, a tail rear light, a side light, an external position light, a direction indicator, a brake light, a fog light, a reverse light, a dipped beam light, a light arranged on the front grill, a high-beam light, or any other type of light that can be installed on a similar vehicle with a motor, preferably a car.

[0034] With reference to an example embodiment shown in Figure 1, the automotive lighting unit 1 may comprise, for example: a rear shell 2 preferably, but not necessarily, shaped like a cup so as to have an internal cavity. The rear shell 2 may be structured, for example, so as to preferably, but not necessarily, be built in, for example, within a compartment formed on the vehicle body (not illustrated).

[0035] According to the example illustrated in Figure 1, the automotive lighting unit 1 may comprise, in addition, preferably one or more front lenticular bodies 3 (only one of which is shown in Figure 1) made, for example, at least partially of transparent or semi-transparent material. The front lenticular body 3 may be structured so it can be coupled to the rear shell 2. The front lenticular body 3 may preferably be arranged at the mouth of the rear shell 2 so as, preferably, to at least partially emerge from the vehicle body (not illustrated).

[0036] According to a preferred embodiment shown in Figure 1, the automotive lighting unit 1 comprises, in addition, at least one electronic lighting device 4, which may, preferably but not necessarily, be arranged inside the automotive lighting unit 1, for example in the rear shell 2.

[0037] According to the preferred embodiment of this invention, the electronic lighting device 4 may comprise one or more LED displays 5 and an electronic control unit 6 that is designed to control the LED display/s 5 according to the method described below.

[0038] The LED display 5 is an emissive display with a LED matrix 8. The LED display 5 consists of a LED panel that directly emits light without any liquid crystal panel and/or layer next to the LEDs 8. In other words, the LED display 5 used according to this invention does not comprise any liquid crystal panel. The light emitted by the automotive lighting unit consists, therefore, of the light directly emitted/generated by the LEDs 8 of the LED display 5.

[0039] The LED display 5 may preferably be conveniently arranged in the automotive lighting unit 1 so as to directly or indirectly face the front lenticular body 3 to perform a lighting function and/or any automotive lighting function (at least those mentioned above), preferably outside the vehicle (Figures 6a, 6b, and 6c).

[0040] With reference to Figures 1 and 4, according to the present invention, the LED display 5 comprises a LED matrix. The LED matrix comprises, in turn, multiple LED arrays 7 each comprising multiple LEDs 8. In the example shown in Figure 4, the LED arrays 7 of the LED matrix are arranged between them so as to respectively form rows of LEDs 8 of the LED display 5.

[0041] It is understood that this invention is not limited to the control of an LED display 5, wherein the LED arrays 7 form the rows of the LED display 5, but may be applied in a very similar way to embodiments wherein the LED arrays 7 are arranged so as to form/define the columns of the LED display 5.

[0042] According to a preferred embodiment, the LED display 5 has a mini-LED architecture. Conveniently, the LED display 5 is a display with passive matrix mini-LED architecture. According to a preferred embodiment, the LED display

5 may have a micro-LED architecture. Conveniently, the LED display 5 is a display with passive matrix micro-LED architecture.

[0043] As shown in the example in Figure 4, the circuit architecture of a passive matrix mini-LED display comprises multiple inputs 9 and 10. The inputs 9 are designed to be used to perform the selective switching of the LED arrays 7 (defining the rows of the LED display 5 matrix in Figure 4). In the example shown in Figure 4, the inputs 10 are designed to be used to perform the selective control of the currents fed to the LEDs 8 present in each LED array 7.

[0044] With reference to Figures 1 and 2, the electronic control unit 6 comprises a control driver 11 and, preferably, the driving drivers indicated in the figures with 12 and 13.

[0045] The driving drivers 12 may be provided with an electronic switching circuit comprising, for example, electronic switches (shown in Figure 4). The electronic switches may be connected, respectively, to the inputs 9 (Figure 4). Each electronic switch may be activated/controlled based on a corresponding command signal C1 to cause the opening or, alternatively, the closing of a common electric line LC connecting the LEDs 8 in the LED array 7 associated with a corresponding input 9.

[0046] When the common connecting circuit line LC of the LEDs 8 in an LED array 7 is electrically closed, the LED array 7 is electrically active. The command signal C1 codifies, i.e., is indicative of, an activation interval TA during which the LED array 7 associated with the closed switch is electrically active in response to the command signal C1. When the LED array 7 is electrically active, its LEDs 8 may be traversed by currents selectively controlled by the driving driver 13.

[0047] Vice versa, when the common connecting circuit line LC of the LEDs 8 in an LED array 7 is electrically open, the LED array 7 is electrically deactivated (switched off). When the LED array 7 is electrically deactivated, the currents are interrupted and the corresponding LEDs 8 remain switched off.

[0048] The driving driver 12 may preferably provide PWM command signals C1. The width TON of the pulse of the command signal C1 is varied by the driving driver 12 depending on the activation interval TA of the LED array 7.

[0049] With regard to the driving driver 13, it may comprise an electronic supply circuit designed to selectively (and in a controlled manner) supply the currents to the LEDs 8 of the LED arrays 7.

[0050] The electronic supply circuit is represented in Figure 4 via a series of current supply sources, which supply, in a controlled manner, the currents to the inputs 10 based on the respective command signals C2.

[0051] The driving driver 13 may generate PWM command signals C2, wherein the width TON of the PWM pulse is varied based on the current to be supplied to the LED 8. The current to be supplied to the LED 8 may be associated with a numeric value that is indicative of the light intensity that the LED 8 provides.

[0052] When the LED array 7 is electrically active, the currents are designed to traverse the LEDs 8 so as to switch them on and cause the emission of a light intensity, which depends on the command signal C2, from the LEDs 8 themselves.

[0053] With reference to Figures 1 and 2, the control driver 11 is electrically connected to the driving drivers 12 and 13 to supply the command signals C1 and C2 to the drivers in order to control the operation of the LED display 5. It is understood that the driving drivers 12 and 13 and the control driver 11 may be integrated in a single electronic device or circuit or be separated between them and defined by as many other electronic devices or circuits.

[0054] According to the present invention, the control driver 11 is configured in order to receive, as input, and preferably in a sequential way and at pre-determined intervals, image frames F1, and is designed to generate the command signals C1 and C2 to drive (in the way described below) the LEDs 8 of the LED display 5 based on the image frames F1 received.

[0055] The image frames F1 received are preferably configured so as to cause, when they are implemented by the control driver 11, the generation of static and/or dynamic images via the LED display 5. Dynamic images are images that change over time (moving images).

[0056] As shown in the example in Figure 3, the image frame F1 may be represented by a numeric matrix. The numeric matrix may have, for example, the row/column dimensions of the LED matrix of the LED display 5 to control. The numeric matrix is divided into rows and columns wherein each row comprises a data array D(i) (wherein "i" is an index of the row number ranging between 1 and NT, indicating the total number of rows). The data contained in each data array D(i) are respectively associated with the LEDs 8 of a corresponding LED array 7 of the LED display 5 and contain numeric values V(i,j) that are indicative of the light intensities to be generated via said LEDs 8 of the LED array 7 during a display interval or refresh interval TR of the image associated with the image frame F1.

[0057] In the example that follows, without losing any generality thereby, a numeric value "zero" contained in the image frame F1 indicates zero light intensity and thus codifies a corresponding switched-off LED 8. A numeric value contained in the image frame F1 other than zero indicates/codifies the light intensity of a switched-on LED 8.

[0058] A data array D(i) of the image frame F1 codifies a switched-off state of a corresponding LED array 7, when its numeric values V(i,j) are indicative of the switching-off of all the LEDs 8 of the LED array 7 itself.

[0059] Vice versa, a data array D(i) of the image frame F1 codifies a switched-on state of a corresponding LED array 7, when its numeric values V(i,j) are indicative of the switching-on of several LEDs 8 of the LED array 7 itself.

[0060] With reference to the example image frame F1 shown in Figure 3, the switched-off state occurs when all the numeric values V(i,j) of the data array D(i) defined by a row are zero. Vice versa, the switched-on state occurs when

one or more numeric values V(i,j) of the data array D(i) of a row are not zero. In the example illustrated in Figure 3, the data arrays D(i) from D(1) to D(6) and from D(28) to D(32) all have numeric values V(i,j) at zero and codify the switched-off state of the corresponding LED arrays 7 while the remaining data arrays from D(7) to D(27) have numeric values V(i, j) other than zero and codify the switched-on state of the corresponding LED arrays 7.

[0061] According to this invention, the control driver 11 is configured so as to process the image frame F1 in order to determine, in the same, the data arrays D(i) that codify the switched-off state of the corresponding LED arrays 7 of the LED display 5 during the refresh interval TR.

[0062] The control driver 11 is also configured so as to process the image frame F1 in order to determine, in the same, the data arrays D(i) that codify the switched-on state of the corresponding LED arrays 7 of the LED display 5 during the refresh interval TR.

[0063] According to this invention, the control driver 11 is also configured so as to determine the activation intervals TA of the LED arrays 7 based on the data arrays D(i) of the image frame F1, which codify the switched-on state during the refresh interval TR.

[0064] It is understood that, in addition or alternatively, the control driver 11 may also be configured so as to determine the activation intervals TA of the LED arrays 7 based on the data arrays D(i) of the image frame F1, which codify the switched-off state during the refresh interval TR.

[0065] According to a preferred embodiment, the control driver 11 is also configured so as to process the image frame F1 in order to determine the number N1 of data arrays D(i), which codify the switched-on state and determines the corresponding activation intervals TA based on the number N1 determined and the refresh interval TR.

[0066] It is understood that, in addition or alternatively, the control driver 11 may also be configured so as to determine the number N2 of data arrays D(i), which codify the switched-off state and determines the corresponding activation intervals TA based on the number N2 determined and the refresh interval TR.

[0067] According to the embodiment wherein the activation intervals of the arrays are controlled via the PWM command signals C1, the control driver 11 may modify/vary, for each image frame F1 received, the duration TON of the command signal C1 pulses based on the activation intervals TA determined.

[0068] According to a possible embodiment, the duration TON of the command signal C1 may be increased proportionally to the number N2 of data arrays D(i) of the image frame F1 that codify the switched-off state.

[0069] It is understood, vice versa, that the duration TON of the command signal C1 may be decreased proportionally to the number N1 of data arrays D(i) of the image frame F1 that codify the switched-on state.

[0070] The control driver 11 may preferably determine the duration TON of the command signal C1 (PWM), dividing the refresh interval TR by the number N2 of data arrays D(i) that codify the switched-on state.

[0071] The control driver 11 may also preferably determine the duration TON of the command signal C1 (PWM), dividing the refresh interval TR by the difference between the total number NT of data arrays D(i) and the number N2 of data arrays D(i) that codify the switched-off state.

[0072] In this case, the duty cycle $\delta C1$ of the command signal C1 (PWM) may be calculated based on the following relationship:

$$a)\quad \delta C1=[1/(NT-N1)]*100$$

wherein NT is the total number of data arrays D(i) (rows in Figure 3) in the image frame F1, or

$$b)\quad \delta C1=[1/(N2)]*100$$

[0073] The control driver 11 is also configured so as to command, during the refresh interval TR, the sequential and selective electric activation, one after the other, of the LED arrays 7 of the LED display 5 corresponding to the data arrays D(i) that codify the switched-on state, based on the activation intervals TA determined and to prevent, at the same time, the remaining LED arrays 7 associated with the data arrays D(i) that codify the switched-off state from being electrically activated.

[0074] The technical effect obtained is that, on the one hand, of eliminating the activation intervals associated with the LED arrays 7 in the switched-off state that do not provide any contribution to the average intensity value of light generated by the LED display 5 in the refresh interval TR, and, on the other, to increase in a controlled way the activation interval TA of the switched-on LEDs 8 that contribute to increasing the average intensity value of light generated by the automotive lighting unit 1 in the refresh interval TR.

[0075] The Applicant has found that this solution is particularly advantageous in passive matrix mini-LED displays wherein the sequential activation of the "rows" of LEDs 8 is required, i.e., of the LED arrays 7, one at a time, in the corresponding activation intervals TA. Given that the light intensity generated by the LED display 5 in a refresh interval

TR is calculated as an arithmetic average of the light intensities generated by the LED arrays 7 in the refresh interval TR, it is possible to increase/decrease in a controlled way the value of the same by increasing/decreasing the activation intervals TA of the LED arrays 7 based on the switched-off/switched-on states codified in the data arrays D(i) that define the image frame F1.

[0076] In this way, the switching of the LED arrays 7 that are intended to remain switched off is, thus, "skipped" so as to conveniently use their activation intervals TA to increase the activation intervals of the LED arrays 7 that, during the refresh interval, are intended to be switched on. This makes it possible to conveniently increase the average light intensity of the light emitted by the LED display 5 without increasing the currents supplied to the LED arrays 7 that are switched on and thus improves the efficiency of the LED display 5.

[0077] Figure 5 shows a flow chart containing an operation method for the electronic lighting device 4 according to one embodiment, wherein it is imagined that the control driver 11 comprises a register circuit 11a and a memory 11b (Figure 2) .

[0078] The register circuit 11a is configured so as to store a series of status bits, preferably equal to the number NT of LED arrays 7 of the LED display 5. Each status bit is associated with a corresponding data array associated, in turn, with an LED array 7, and indicates whether the data array D(i) of the image frame F1 codifies the switched-off state or the switched-on state of the LED array 7. For example, a status bit equal to 1 codifies the switched-on state of the data array D(i) and, vice versa, a status bit equal to 0 codifies a switched-off state of the same.

[0079] The memory 11b is designed to store the image frames F1 received and used to control the LED display 5.

[0080] With reference to Figure 5, the method envisages that the control driver 11 of the electronic control unit 6 receives the image frame F1 from the vehicle electronic control unit 100 (block 100). It is understood that the image frame F1 may be provided with a control unit present within the light 1.

[0081] The image frame F1 received is temporarily stored by the control driver 11 in the memory 11b (block 110).

[0082] The control driver 11 controls the data arrays D(i) of the image frame F1 and determines the data arrays D(i) that codify a switched-off state and/or a switched-on state.

[0083] Conveniently, the control driver 11 determines, in sequence, one after the other, for each data array D(i) the corresponding switched-on state and/or switched-off state based on the numeric values V(i,j) contained therein (block 120). In the example illustrated, for each data array D(i), the control driver 11 adds the numeric values V(i,j) (block 120) and determines the switched-on state if the sum is greater than zero, or, vice versa, determines the switched-off state if the sum is equal to zero.

[0084] In the example illustrated, the control driver 11 checks whether the sum of the numeric values V(i,j) of all the data arrays (block 130) is complete. If not (output NO from block 130), the control driver 11 checks, for each data array D(i), whether the sum is zero or other than zero (block 140).

[0085] If the sum of the numeric values V(i,j) of the data array D(i) is zero (output YES; block 140), the control driver 11 assigns the value zero (block 150) to the status bit of the register circuit 11a and passes to the subsequent data array D(i) and implements the block 130 operation again.

[0086] If the sum of the numeric values V(i,j) of the data array D(i) is other than zero (output NO; block 140), the control driver 11 assigns the value 1 (block 160) to the status bit of the register circuit 11a and passes to the subsequent data array D(i) and implements the block 130 operation again.

[0087] When the control driver 11 has completed the verification of the status of all the data arrays D(i) of the image frame F1 (output YES; block 130), the control driver 11 determines the activation times TA based on the switched-on and switched-off states determined (block 170).

[0088] In this step, the control driver 1 may determine, for example, the number N1 of data arrays that codify the switched-on state based on the unitary status bits present in the register circuit 11a, and determines the activation times TA based on the number N1 and the refresh interval TR stored in the memory 11b and/or of the number N2.

[0089] In this step, the control driver 11 changes the duty cycle $\delta C1$ to be used to switch the LED arrays 7 associated with the data arrays D(i) in the switched-on state based on the activation times TA determined.

[0090] It is understood that the duty cycle $\delta C1$ may be determined via the relationships a) or b) described above.

[0091] During the refresh interval TR associated with the display of the image frame F1, the control driver 11 sequentially commands, one after the other, the electric activation of the LED arrays 7 associated with the data arrays D(i) in the switched-on state during the corresponding activation intervals TA.

[0092] During the activation interval TA of each of the LED arrays 7, the control driver 11 generates the command signals C2 to switch on the LEDs 8 of the LED array 7 based on the numeric values V(i,j) present in the corresponding data arrays D(i) of the stored image frame F1.

[0093] According to the flow chart in Figure 5, the method starts the refresh interval TR to display the image relating to the image frame F1 (block 180).

[0094] The control driver 11 checks in the register circuit 11a whether the bit associated with the LED array 7 is one or zero (block 190). If yes (output yes; block 190), the control driver 11 commands, via the command signal C1, the electric activation of the LED array 7 and keeps it active for an activation interval corresponding to the duration TON of

the pulse of the command signal C1 (block 200) before switching it off at the end of TON.

At the end of the duration TON, the control driver 11 checks in the register circuit 11a whether the bit associated with the successive LED array 7 is one or zero (block 220). Subsequently, in block 230, the control driver 11 checks whether the data frame F1 in the memory 11b is changed (block 230) and, if not, i.e., if the refresh interval TR has not ended, the control driver 11 re-performs the block 190 operation and the successive ones described in blocks 200-230. If yes (output yes), i.e., the data frame F1 in the memory 11b is changed and the refresh interval TR has ended, the control driver 11 repeats the operations described above, beginning from block 100.

If the status bit of the register circuit 11a associated with the LED array 7 is zero (output No from block 190), the control driver 11 directly performs the block 220 operations, skipping, in this way, the activation of the LED array 7 associated with the zero bit.

The operations indicated in blocks 100-230 are repeated for each new image frame F1 received from the control driver 11 from the vehicle electronic control unit 100 (or from the control unit in the light 1).

[0095] The embodiment shown in Figure 7 relates to an electronic lighting device 40, which is similar to the first electronic lighting device 4, and the parts of which will be identified, where possible, with the same reference numbers that identify corresponding parts of the electronic lighting device 4. In particular, the electronic lighting device 40 differs from the first electronic lighting device 4 due to the fact that it comprises a control driver 41 comprising a timing unit 44, a timer 45, a multiplexer 47, and a counter 46.

[0096] The timing unit 44 may be configured so as to determine the number of unitary status bits in the register circuit 11a and determine the activation interval TA, preferably corresponding to the TON of the command signal C1 for each LED array 7 based on the number N1.

[0097] The timer 45 is configured to measure the time and provides an output signal indicative of the period of the activation interval TA.

[0098] The counter 46 may be configured to count the number of pulses of the command signals C1 and increases a value of the multiplexer 47 and a register circuit index of data arrays D(i). The maximum value of the counter 46 may be equal to NT.

[0099] The multiplexer 47 is designed to switch the LED arrays 7 based on the command signals C1. It is understood that the multiplexer 47 may be integrated with the driving driver 12.

[0100] Figure 8 shows a flow chart for the operation of the electronic lighting device 40, which is similar to the operation of the electronic lighting device 4 schematically shown in the flow chart shown in Figure 5, and the blocks of which will be identified, where possible, with the same reference numbers that identify corresponding operation blocks of the flow chart in Figure 5 relating to the electronic lighting device 4.

[0101] In particular, as shown in Figure 8, the method involves implementing the operations of the flow chart in Figure 5 described above, specifically by block 100 to block 160. At the end of the calculation of the status bits of all the data arrays D(i) of the image frame F1 (output yes; block 130), the timing unit 44 calculates the TON of the command signals C1 (block 300) as described above.

[0102] In the successive block 310, the control driver 11 starts the refresh interval TR, controls the status bits present in the register circuit 11a associated with a corresponding LED array 7 and, for the unitary status bits, performs the block operations below.

[0103] In block 320, at the same time: the LED array 7 associated with the unitary bit is activated using the multiplexer 47, the counter 46, which increases its count by one unit, is activated, and the timer 45 that measures time.

[0104] When the time measured by the timer 45 reaches the activation interval TA, the electrically active LED array 7 is deactivated and the LED array 7 associated with the successive unitary status bit in the register circuit 11a (block 330) is electrically activated. It is also checked whether the count of the counter 46 has reached the number NT (block 340). If not (output No; block 340), the counter 46 increases its count (block 360) by one unit and repeats the operations required by blocks 320-350.

[0105] If yes, i.e., if the count of the counter 46 has reached the number NT (output yes; block 340), the method starts the counter 46 again and repeats the operation required by block 230 in order to repeat the operations from 100 to 360 for the successive image frame F1.

[0106] In addition to the operations described, in each of the two flow charts in Figures 5 and 8, the method according to this invention may also conveniently implement the operations described in blocks 500-620 in the flow chart shown in Figure 9.

[0107] As shown in Figure 9, the method stipulates that the control driver 11 determines an intensity value IM of the LED display 5, adding the numeric values V(i,j) contained in the data array D(i) of the image frame F1.

[0108] The control driver 11 compares the intensity value IM with a predetermined intensity threshold TI.

[0109] If the intensity value IM is lower than the predetermined intensity threshold TI, the control driver 11 increases the numeric values V(i,j) of the image frame F1. The numeric values V(i,j) of the image frames F1 may, preferably, be increased to ensure that the intensity value IM reaches the predetermined intensity threshold.

[0110] In the discussion that follows, an image frame F1 will be considered in which the numeric values V(i,j) codify,

in the form of bits, the duty cycle of the command signals C2 that control the currents selectively fed to the LEDs 8 of the LED array 7 electrically activated by the command signal C1.

[0111] According to this embodiment, the method may increase the durations TON of the PWM command signals C2 codified via the numeric values V(i,j) to ensure that the intensity value IM reaches the predetermined intensity threshold. The numeric values V(i,j) of the image frame will, thus, be indicated in the discussion that follows with PWM values.

[0112] The method starts with block 500, in which the vehicle electronic control unit 100 provides the image frame F1 to the electronic control unit 6 that stores it in the memory 11b (block 510).

[0113] In block 520, the control driver 11 calculates the sum of the PWM values contained in the data arrays D(i) of the image frame F1 and the number M of PWM values that indicate that the LEDs 8 are switched on.

[0114] In block 530, the control driver 11 calculates a maximum light intensity IMAX-LED associated with an LED 8.

[0115] In block 540, the control driver 11 determines the light intensity Ilbit associated with a bit with the PWM value. For example, I1bit=IMAX-LED/PWM wherein PWM is the maximum pulse width in bits of the command signal C2.

[0116] In block 550, the control driver 11 calculates the intensity $PWM_{DISPLAY}$ of light of the LED display 5 during the refresh interval TR based on the sum of the PWM values contained in the data arrays D(i).

[0117] In block 560, the control driver 11 compares the intensity $PWM_{DISPLAY}$ of light of the LED display 5 with a target intensity PWMtarget. It is useful to specify that PWMtarget depends on the lighting function that the LED display 5 must perform and may be modified during the operation of the LED display 5, for example the transition from TAIL to STOP.

[0118] For example, in this block, it may be checked whether the following condition is true:

$$c) \quad PWM_{DISPLAY} = PWM_{TARGET}$$

[0119] If the intensity $PWM_{DISPLAY}$ of light of the LED display 5 is equal to the target intensity PWM_{TARGET} (output yes; block 560), the control driver 11 checks whether the image frame F1 was changed (block 620) and, if yes, repeats the operations beginning with block 500.

[0120] If no (output no; block 560), the control driver 11 checks whether the intensity $PWM_{DISPLAY}$ of light of the LED display 5 is greater than the target intensity PWM_{TARGET} (block 570) according to the following condition

$$d) \quad PWM_{DISPLAY} > PWM_{TARGET}$$

[0121] If yes (output yes; block 580), i.e., if $PWM_{DISPLAY} > PWM_{TARGET}$, the control driver 11 reduces the PWM values of the data arrays D(i) of the image frame F1 based on the number M of LEDs 8 in the switched-on state and the difference between the intensity $PWM_{DISPLAY}$ of light of the LED display 5 and the target intensity PWM_{TARGET} (block 580) . In this condition, the intensity of the light is enough and the control driver may proportionally lower the intensity of each LED 8, thus reducing the LED display 5 power consumption.

[0122] In this case, the control driver may calculate the new value PWM'_{LED} of each of the PWM values of the LEDs based on the following relationship:

$$e) \quad PWM'_{LED} = PWM_{LED} - \left\lfloor \frac{PWM_{DISPLAY} - PWM_{TARGET}}{M} \right\rfloor .$$

[0123] If no (output no; block 570), the intensity $PWM_{DISPLAY}$ of light of the LED display 5 is less than the target intensity PWM_{TARGET} (block 590), i.e., the following condition is true:

$$f) \quad PWM_{DISPLAY} < PWM_{TARGET}$$

[0124] In this condition, the intensity of the light is enough and the control driver 11 conveniently increases the intensity of each LED based on the shifting of the $PWM_{DISPLAY}$ from PWM_{TARGET}

[0125] In block 590, the control driver 11 may preferably calculate the new values PWM'_{LED} via the following relationship:

g)

$$PWM'_{LED} = PWM_{LED} + \frac{PWM_{TARGET} - PWM_{ROW}}{M}$$

[0126] Wherein PWM_{LED} is the PWM value in the data array (Di) associated with an LED, PWM_{ROW} is the sum of the PWM values of a data array D(i), and M is the number of LEDs 6 that will be switched on.

[0127] In block 600, the method may compare the new, increased values PWM'_{LED} with a maximum LED intensity PWM_{ON} indicative of the maximum intensity of each LED 8, so as not to exceed the maximum current intensity of each LED 8.

[0128] The maximum LED intensity may be determined, for example, using the following relationship

h):

$$PWM_{ON} = M * PWM$$

[0129] Where M is the total number of active LEDs

[0130] if the PWM value of an LED 8 is greater than the maximum intensity, i.e., $PWM'_{LED} > PWM_{ON}$ (output yes; block 600), the method modifies the values PWM_{OFF} of the image frame F1 indicative of the switched-off LEDs 8. In the condition $PWM'_{LED} > PWM_{ON}$ the light intensity required is greater than that which the active LEDs 8 are able to deliver.

[0131] In particular, the method may modify each of the values PWM_{OFF} of the image frame F1 indicative of the switched-off LEDs 8 using the following relationship:

i)

$$PWM_{OFF} = \left\lceil \frac{PWM_{TARGET} - PWM_{ON}}{C - M} \right\rceil$$

[0132] Wherein C is the total number of LEDs 8 of the LED display 5.

[0133] After having implemented the block operations 580, 600, 610 described above, the method generates, via the control driver 11, the command signals C2 modulated based on the numeric values V(i,j) present in the image frame F1 so as to selectively power the currents to the LEDs 8 of the LED arrays 8 in the switched-on state.

[0134] The light described above makes it possible to respect the light intensity constraints in all operating situations. This makes it possible to customise the image represented in the light without having to set the minimum number of switched-on LEDs.

[0135] The light is, in fact, able to dynamically adapt the intensity of the light in the display thanks to the proportional increase in the duty ON every time rows or columns of LEDs that are OFF are present, so as to keep the intensity above a minimum threshold.

[0136] The solution described above makes it possible to increase the efficiency of the LED displays proportionally to the number of LED arrays in the frame that remain switched off. In addition, it makes it possible to have a constant light intensity that, irrespective of the image represented, can always meet the legal light intensity requirements.

[0137] Finally, it is clear that changes may be made to the light and to the method described and illustrated herein, and variations produced thereto, which do not depart from the scope of protection defined by the claims.

Claims

1. A automotive lighting unit (1) comprising:

a lighting device (4) provided with an emissive LED display (5) comprising a multiple LED arrays (7) arranged in order to form rows and columns of a LED matrix,
characterised in that it comprises a control driver (11) configured to:

receive an image frame (F1) containing a plurality of data arrays (D(i)) which codifies the luminous image to be displayed during a refresh interval (TR) by means of respective LED arrays (7) of said LED display (5), process the image frame (F1) to determine in said image frame (F1), data arrays (D(i)) that codify a first operating condition of first LED arrays (D(i)) in said LED display (5),

determine activation intervals (TA) based on said refresh interval (TR) and data arrays (D(i)) of said image frame (F1) which satisfy said first operating condition,
during said refresh interval (TR), control the sequential and selective activation, one after the other, of said first LED arrays (7) based on the activation intervals (TA) determined, and prevent the remaining LED arrays (7) from being activated.

2. The automotive lighting unit according to claim 1, wherein said first operating condition is a switched-on condition for said first LED arrays (7) of said LED display (5) wherein said first LED arrays (7) have one or more LEDs (8) switched on.

3. The automotive lighting unit according to claim 2, wherein said control driver (11) is configured to increase the activation intervals (TA) of said first LED arrays (7), in inverse proportion to the number of data arrays (D(i)) that codify said switched-on state.

4. The automotive lighting unit according to claim 1, wherein said first operating condition is a switched-off condition for said first LED arrays (7) of said LED display (5) wherein the first LED arrays (7) have all the LEDs (8) switched off.

5. The automotive lighting unit according to claim 4, wherein said control driver (11) is configured in order to increase the activation intervals (TA) of said first LED arrays (7), in proportion to the number of data arrays (D(i)) that codify said switched-off state.

6. The automotive lighting unit according to any of the preceding claims, wherein the control driver (11) is configured in order to: determine the number of data arrays (D(i)) of said image frame (F1) that codify said first operating condition, and determine the activation times (TA) based on said number of data arrays (D(i)) and of said refresh interval (TR).

7. The automotive lighting unit according to any of the preceding claims, wherein said control driver (11) is configured in order to generate first PWM command signals (C1) to selectively activate, one after the other, said LED arrays (7) of said LED display (5), said control driver (11) also being configured to vary the duty cycle of said first PWM command signals (C1) based on said determined activation times (TA).

8. The automotive lighting unit according to any of the previous claims, wherein the data arrays (D(i)) of said images frame (F1) comprises LED values associated with the light intensities to be generated via the LEDs (8) of said LED arrays (7), said control driver (11) is also configured in order to: calculate a first value containing the sum of said LED values of said image frame, compare said first value with an intensity threshold, modify the LED values of the data arrays (D(i)) that codify the switched-on state based on said comparison, maintain the LED values of the data arrays (D(i)) that codify the switched-off state.

9. The automotive lighting unit according to claim 8, wherein said control driver (11) is also configured in order to increase the LED values in the data arrays (D(i)) that codify the switched-on state, when the first value is less than said intensity threshold.

10. The automotive lighting unit according to claim 9, wherein said control driver (11) is also configured so as to compare the LED values in the data arrays (D(i)) that codify the switched-on state with a maximum LED intensity threshold and modify the LED values of the data arrays (D(i)) that codify the switched-off state when said LED values are greater than said maximum LED intensity threshold.

11. The light according to any of the previous claims, wherein said LED display (5) comprises a mini-LED display and/or a micro-LED display, with passive matrix.

12. The light according to any of the previous claims, wherein said LED display (5) does not comprise any liquid crystal panel.

13. An operation method for an automotive lighting unit (1) comprising:
a lighting device (4) provided with an emissive LED display (5) comprising a plurality of LED arrays (7) arranged so as to form rows and columns of an LED matrix, said method being **characterised in**:

receiving an image frame (F1) containing a plurality of data arrays (D(i)) that codify the luminous image to be

displayed during a refresh interval (TR) by respective LED arrays (7) of said LED display (5),
processing the image frame (F1) to determine in said image frame (F1) the data arrays (D(i)) that codify a first operating condition of first LED arrays (7) in said LED display (5),
determining the activation intervals (TA) based on said refresh interval (TR) and the data arrays (D(i)) of said image frame (F1) which satisfy said first operating condition,
during said refresh interval (TR), controlling the sequential and selective activation, one after the other, of said first LED arrays (7) based on the activation intervals (TA) determined, and prevents the remaining LED arrays (7) from being activated.

14. The method according to claim 13, wherein said first operating condition is a switched-on condition for said first LED arrays (7) of said LED display (5) wherein the first LED arrays (7) have one or more LEDs (8) switched on.

15. The method according to claim 14, comprising the step of increasing the activation intervals (TA) of said first LED arrays (7), in inverse proportion to the number of data arrays (D(i)) that codify said switched-on state.

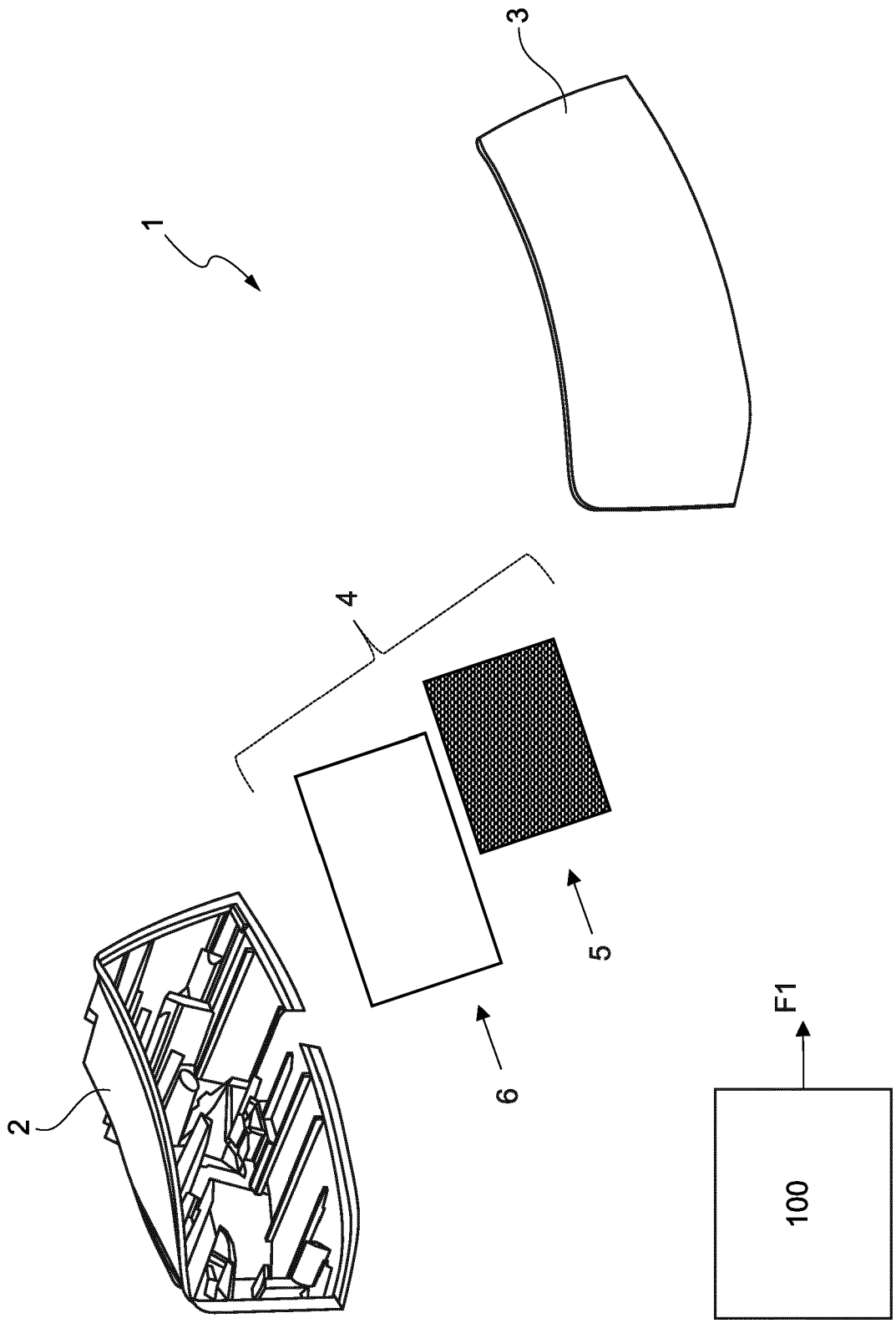


FIG. 1

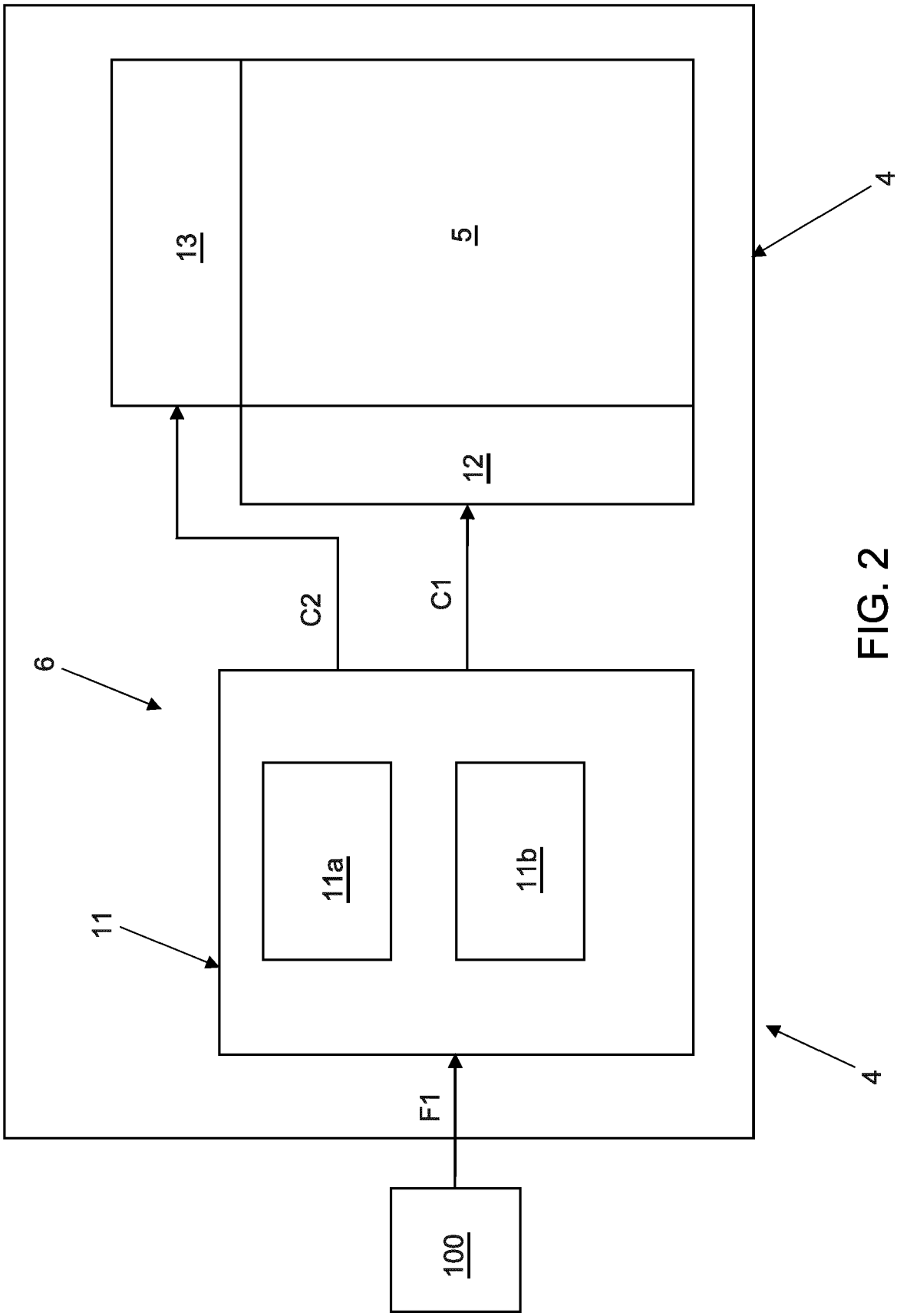


FIG. 2

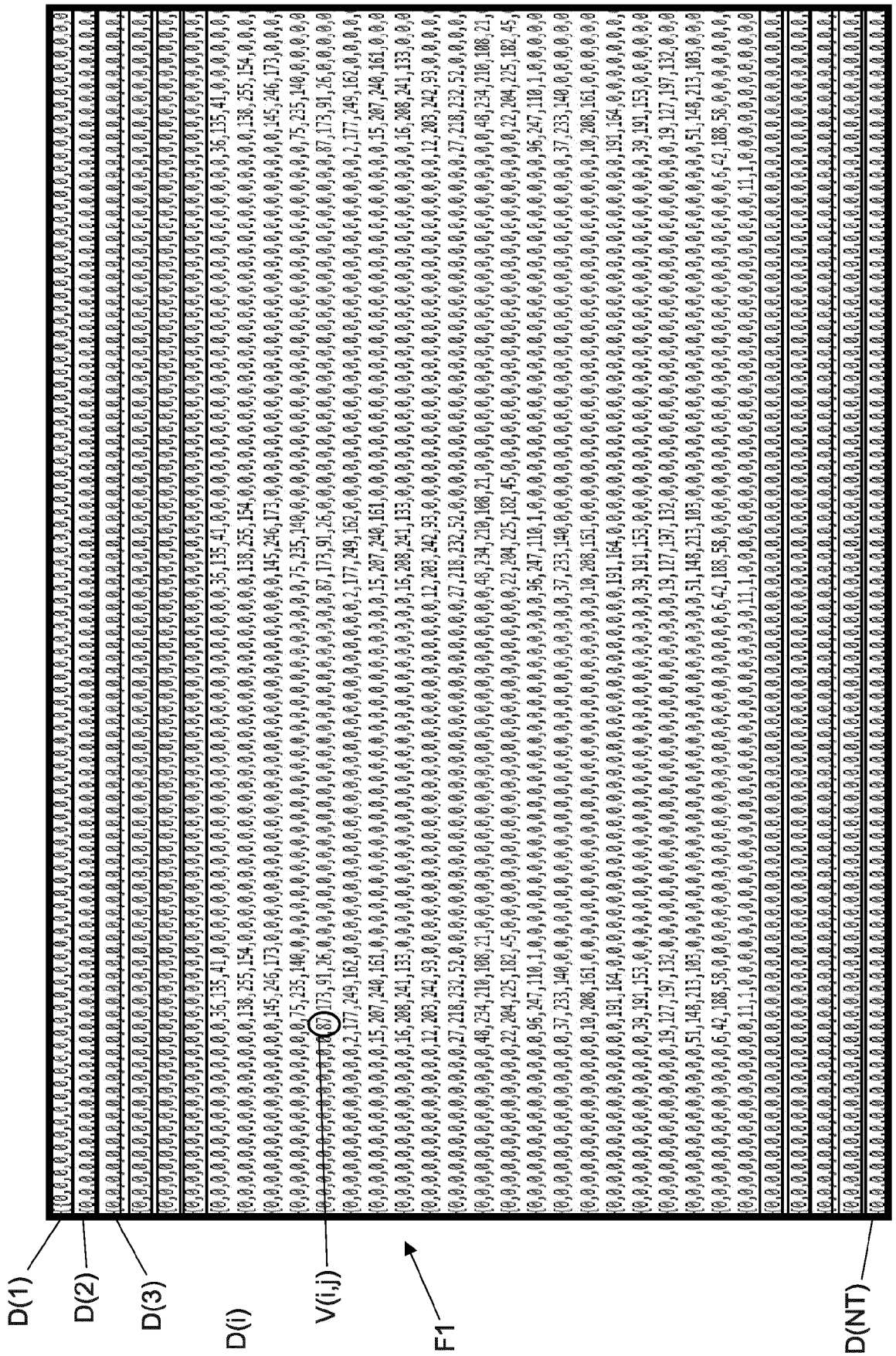


FIG. 3

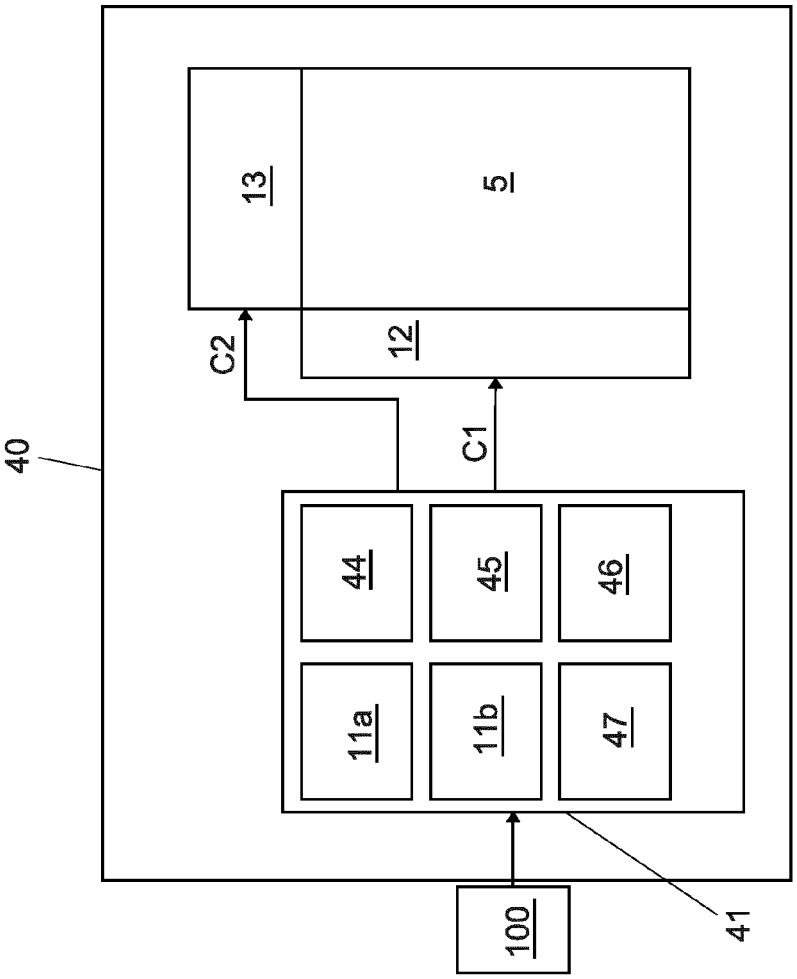

40
13
5
12
C2
C1
44
45
46
11a
11b
47
100
41

FIG. 7

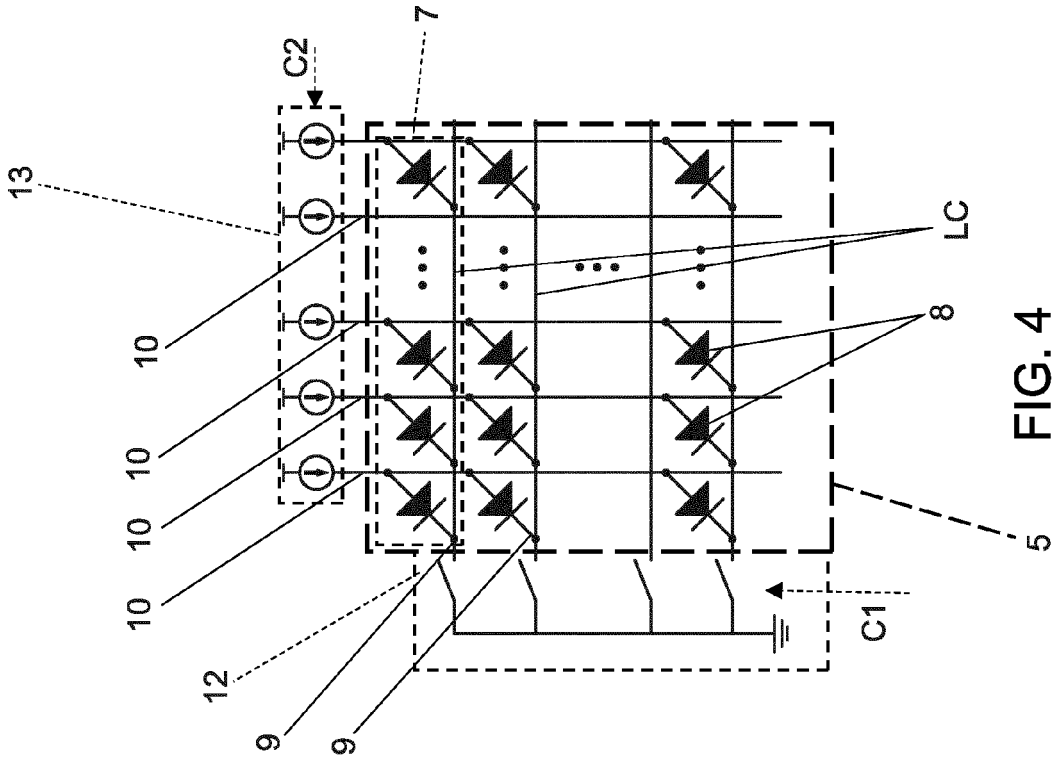

C2
7
13
10
10
10
10
LC
8
5
12
9
9
C1

FIG. 4

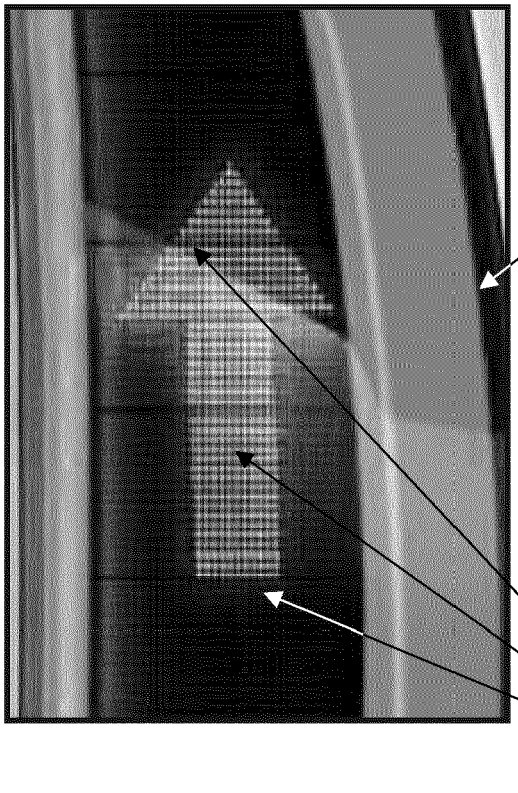


FIG. 6b



FIG. 6a

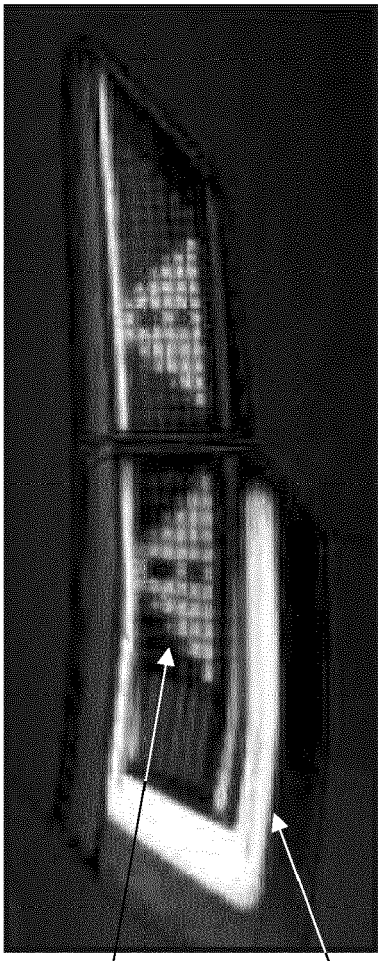


FIG. 6c

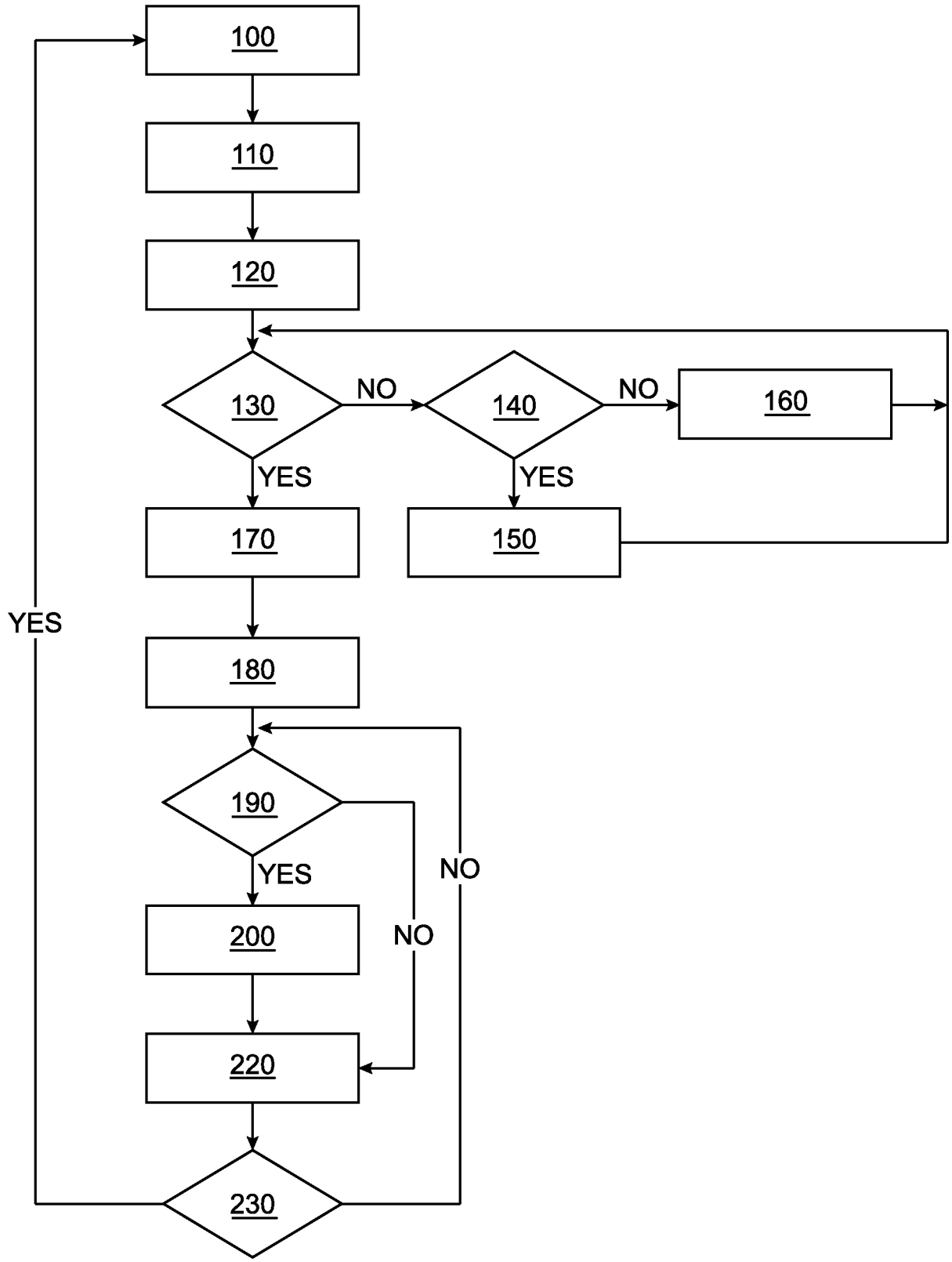

100
110
120
130
NO
140
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160
YES
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170
150
YES
180
190
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NO
NO
200
220
230

FIG. 5

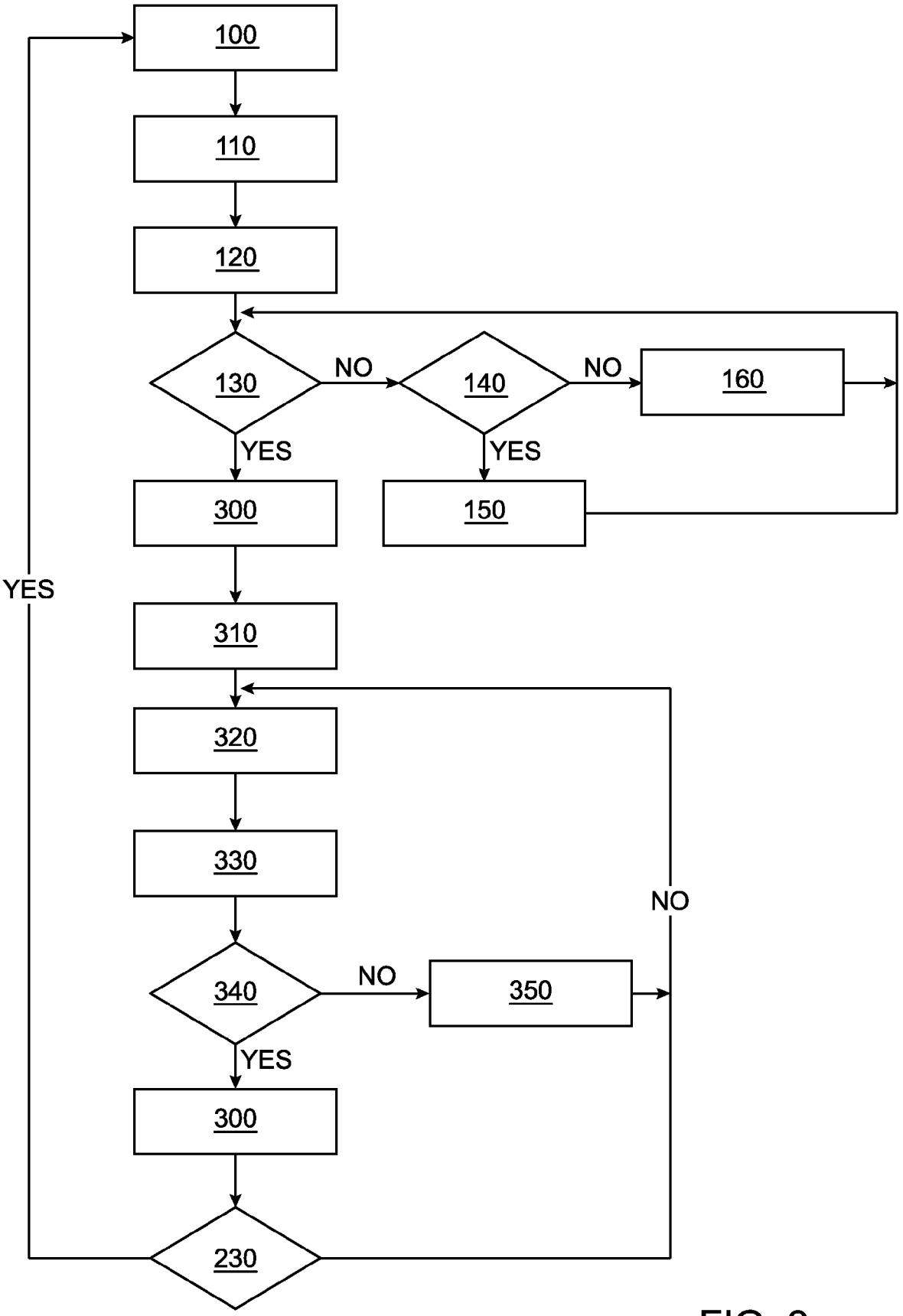

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120
130
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310
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300
230

FIG. 8

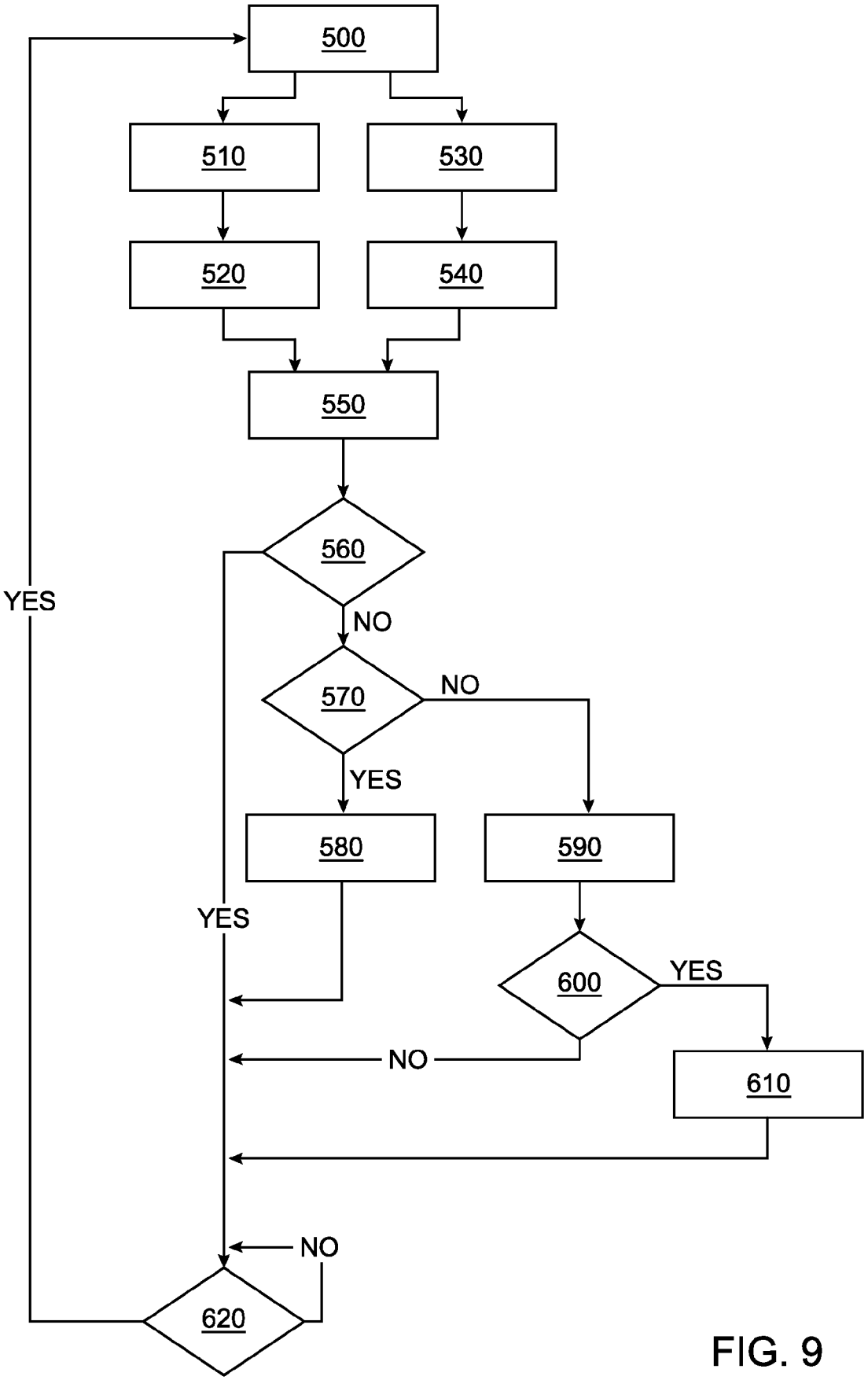

500
510
530
520
540
550
560
YES
NO
570
NO
YES
580
590
YES
600
YES
NO
610
NO
620

FIG. 9

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EUROPEAN SEARCH REPORT

Application Number
EP 21 21 5764

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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G09G
H05B
B60Q

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	13 May 2022	Adarska, Veneta

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