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(71) Applicant: **Vestel Elektronik Sanayi ve Ticaret A.S.**
45030 Manisa (TR)

(72) Inventor: **SANCAK, Mesut**
45030 Manisa (TR)

(74) Representative: **Ascherl, Andreas et al**
KEHL, ASCHERL, LIEBHOFF & ETTMAYR
Patentanwälte - Partnerschaft
Emil-Riedel-Strasse 18
80538 München (DE)

(54) **BACKLIGHT SYSTEM AND METHOD**

(57) The present invention provides a backlight system (1, 1000) for a display device (2), comprising a current source (3, 1001) configured to provide a driving current (4), a number of lighting units (7 - 16, 1000B) connected to the current source (3, 1001) and comprising a plurality of light generation devices (17; 101 - 400, 1004, 1006) connected electrically in series, wherein the lighting units (7 - 16, 1000B) are connected electrically in parallel to the current source (3, 1001), at least one current modulator (5, 1002) configured to modulate the driving current (4) according to local dimming information (6), and a number of local dimming controllers (18; 401 - 700, 1003, 1005) for each lighting unit (7 - 16, 1000B), the local dimming controllers being connected to a number light generation devices (17; 101 - 400, 1004, 1006) of the respective lighting unit (7 - 16, 1000B) and being configured to dim the respective light generation devices (17; 101 - 400, 1004, 1006) according to the local dimming information (6) provided in the driving current (4). Furthermore, the present invention provides a respective method for controlling a backlight system (1, 1000).

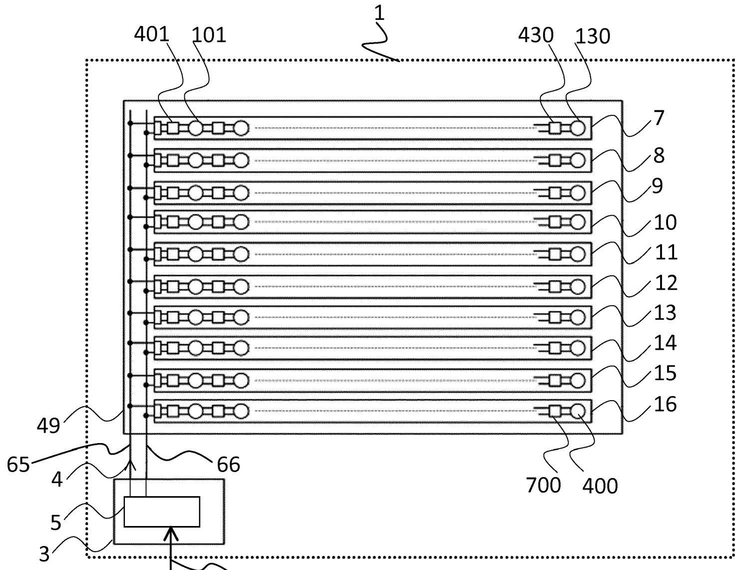

Fig. 1

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Description

TECHNICAL FIELD

[0001] The invention relates to a backlight system for a display device and a corresponding method for controlling a backlight system of a display device.

BACKGROUND

[0002] In modern displays, e.g. LED TVs, a backlight system must be provided, which illuminates an image that is displayed on an active imaging plane of the display. Different types of backlight systems can be used, like e.g. fluorescent lamps, LEDs positioned around the edges of the display, or LEDs evenly distributed behind the surface of the imaging plane.

[0003] Backlight systems with LEDs evenly distributed behind the surface of the imaging plane have the advantage, that sections of the image can be selectively dimmed. This allows dimming e.g. sections with black image content to provide a better black-level reproduction.

[0004] Prion art document US 2015 / 228 227 A1 discloses a system, where a dedicated ASIC or SOC is discretely connected via dedicated control lines to the single LEDs or groups of LEDs, which can be dimmed together.

[0005] This system therefore requires the additional very complex ASIC with a control logic for every single LED and complex cabling in a backlight system.

[0006] Accordingly, there is a need for an improved backlight system for display devices.

SUMMARY

[0007] The present invention provides a backlight system with the features of claim 1 and a method with the features of claim 10.

[0008] The Backlight system for a display device comprises a current source configured to provide a driving current, a number, i.e. one or more, of lighting units connected to the current source and comprising a plurality of light generation devices, like e.g. LEDs or other lamps, connected electrically in series, wherein the lighting units are connected electrically in parallel to the current source, at least one current modulator configured to modulate the driving current according to local diming information, and a number of local dimming controllers for each lighting unit, the local diming controllers being connected to a number light generation devices, i.e. one or more, of the respective lighting unit and being configured to dim the respective light generation devices according to the local diming information provided in the driving current, i.e. setting the brightness of the respective light generation devices.

[0009] The method for controlling a backlight system for a display device, comprises the steps of providing a driving current from a current source to a number of lighting units connected to the current source and each comprising a plurality of light generation devices connected electrically in series, wherein the lighting units are connected electrically in parallel to the current source, modulating the driving current according to local diming information, and dimming the light generation devices according to the local diming information provided in the driving current with a number of local dimming controllers in each lighting unit.

[0010] The backlight system, also called Back Light Unit or BLU, can be used to provide a display device with the ability of locally dimming the backlight of the display device according to an image displayed on the screen.

[0011] The present invention acknowledges the fact, that in common BLUs local dimming is only possible with dedicated ASICs or specifically programmed FPGAs, which are separately connected to every single back light or backlight zone, therefore requiring a complex cabling from the ASIC to the respective lights or zones.

[0012] The backlight system according to the present invention provides lighting units, which in a display device can be evenly distributed behind the active imaging plane, e.g. a LCD, of the display device. Consequently, the single light generation devices are also evenly distributed behind the active imaging plane.

[0013] Every lighting unit can comprise one or more local dimming controllers, which each locally connect to a number, i.e. one or more, of light generation devices of the respective lighting unit. The local dimming controllers each are capable of selectively dimming the light generation devices they are connected to according to local dimming information. Dimming in this context refers to controlling the brightness of the respective light generation devices.

[0014] The local dimming information required by the local dimming controllers is provided by at least one current modulator, which modulates a driving current that is provided by a current source of the backlight system to all lighting units. The local dimming information can be provided to the current modulator e.g. by a video processor, which calculates the local dimming information from video data, which is displayed on the imaging plane of the display device. In order to extract the local dimming information and apply this information adequately, each local dimming controller is capable of demodulating the modulated driving current signal.

[0015] The current source distributes the driving current to the single lighting units during normal operation of the backlight system, even without any local dimming activity, via respective current transmission lines. Therefore, modulating the transmitted current, allows providing information to all local dimming controllers via the current transmission lines, which are needed in the backlight system anyways. The modulation of the current can be performed according to any adequate modulation scheme. The local dimming information can e.g. be embedded in a high frequency current signal, which is added by the current modulator to the constant current of the current source. For modulating the current signal, a simple line modulation can be used, where every bit is represented by a different absolute current value. Furthermore, a bipolar encoding, a Manchester encoding or a differential Manchester encoding can be used. As no clock signal is transmitted via a separate clock line, if needed the clock for the signal can be established by a synchronisation sequence leading each data frame.

[0016] The current transmission lines can be two single lines, a positive and a negative transmission line, wherein the single lighting units connect in parallel to the two current transmission lines. As an alternative, a single current transmission line and a ground plane can be used. A single lighting unit can be provided in the backlight system, therefore providing all light generation devices in series. Only if the number of light generation devices, and their respective voltage demands, surpass the maximum output voltage of the current source, more than one lighting unit, each comprising a subset of the light generation devices, must be connected to the current transmission lines in parallel.

[0017] Just exemplarily, e.g. if a single lighting unit comprises 30 light generation devices, each requiring a driving voltage of 2V, the required voltage is 60V. If the maximum output voltage of the current source equals said 60V, further light generation devices have to be provided in a second lighting unit connected in parallel to the first lighting unit.

[0018] Summing up, the present invention allows transmitting local dimming information to every single local dimming controller via the current transmission lines provided in the backlight system anyways. Consequently, dimming of every single light generation device becomes possible without requiring a discrete cabling to the single light generation devices. Rather, a bus system is constructed with the current transmission lines.

[0019] Further embodiments of the present invention are subject of the further subclaims and of the following description, referring to the drawings.

[0020] In one embodiment, one local dimming controller can be provided for every light generation device. Furthermore, the local dimming controller can be integrated in the housing of the respective light generation device. This allows providing very simple dimming controllers, which only have to decode the local dimming information for a single light generation device and only need to control a single lighting device.

[0021] In another embodiment, the local dimming controllers can comprise a current sensor for sensing the driving current, a demodulator, which demodulates the local dimming information from the sensed driving current, and a protocol engine, which derives from the local dimming information the respective dimming settings for the light generation devices connected to the respective local dimming controller. The protocol engine can e.g. be implemented as a program in a processor. As an alternative, the protocol engine can also be implemented as a state machine using discrete logic elements, CPLDs, ASICs or the like. This simplifies the state machine and allows reducing the size of the local dimming controller. The actual dimming can e.g. be performed e.g. by a PWM-based modulator.

[0022] In one embodiment, the current modulator can be configured to provide data frames in the driving current, which are shorter than half the period, especially a fourth of the period or a fifth of the period, of the display frequency, with which images are displayed on the display device. For example if the screen updates with a frequency of 100Hz, the respective period is 10ms. According to the above, a data frame would therefore be shorter than 5ms, 2,4ms or 2ms. Such short data frames, if the modulation even influences the brightness of the displayed image, are short enough not to produce any brightness deviations perceptible by the human eye.

[0023] In a further embodiment, the current modulator can be configured to provide in a data frame an address of a light generation device and a respective brightness value. This allows simple addressing of individual light generation devices and instructing the respective local dimming controller to set the respective light generation device to the specified brightness value.

[0024] In one embodiment, the current modulator can be configured to provide in a data frame an identification of an active zone, i.e. a group of light generation devices, and a respective brightness value. An active zone can be a group of light generation devices of one light unit. Nevertheless, the term active zone is not limited to one light unit. Instead, an active zone can also comprise light generation devices of different light units. Therefore, a plurality of light generation devices can be controlled with a single data frame.

[0025] In another embodiment, the local dimming controllers comprise a memory, storing for every connected light generation device the active zones to which the respective light generation device belongs. Accordingly, every light generation device can belong to an arbitrary number of active zones, which is only limited by the size of the memory.

[0026] In one embodiment, the current modulator is configured to provide in a number of data frames, i.e. one or more, a zone setting command for setting up a new zone, the identification of an upper left light generation device of the zone, and the identification of a lower right light generation device of the new zone. The zone setting command can be a command, which indicates to the local dimming controllers, that the following information is not directed to a single light generation device but to a group of light generation devices. The zones are rectangular and defined by two of their cornering light generation devices. This scheme assumes that the light generation devices are placed in rows and columns behind the active imaging plane.

[0027] The zone setting command can also be paired with a brightness value. In this case, the zone setting command in one embodiment defines a one time zone. That means that no information about the respective zone is stored in the local dimming controllers after the brightness value has been set for the respective light generation devices. If the zone is to be provided permanently, the local dimming controllers can store the information about the new zone locally.

[0028] In one embodiment, the identification of a generation device can comprise two coordinates of the light generation device in Cartesian coordinates. Furthermore, the local dimming controllers can be configured to identify a light generation device belonging to the new zone, if the values of the two coordinates of the respective light generation device are between the values of the coordinates of the upper left light generation device, and the values of the coordinates of the lower right light generation device of the new zone. Just as an example and to explain the above calculation scheme, a new zone can be defined by the upper left coordinates of 0, 3 and the lower right coordinates of 10, 13. This example assumes that the upmost outer left light generation device has the coordinates 0, 0 and the first coordinate is the abscissa, x, and the second coordinate the ordinate, y, as usually used in programming graphics applications.

[0029] The local dimming controllers will check for every light generation device if the respective coordinates are between [0, 10], i.e. $0 <= x <= 10$, and [3, 13], i.e. $3 <= y <= 13$, respectively. If this is the case, the respective light generation device belongs to the new zone.

[0030] This scheme allows very quickly controlling an arbitrary number of light generation units, which have not been commonly included in a single group before. Furthermore, only a single data frame is needed to transmit the information for zones of arbitrary sizes, instead of transmitting brightness information to every single light generation device. Depending on the data rate of the modulated current signal, more data frames might be needed. However, the number of data frames will still be much lower than transmitting one data frame for every light generation device of the zone, at least with huge zones comprising a high amount of light generation devices.

BRIEF DESCRIPTION OF THE DRAWINGS

[0031] For a more complete understanding of the present invention and advantages thereof, reference is now made to the following description taken in conjunction with the accompanying drawings. The invention is explained in more detail below using exemplary embodiments, which are specified in the schematic figures of the drawings, in which:

Fig. 1 shows a block diagram of an embodiment of a backlight system according to the present invention;

Fig. 2 shows a diagram of an embodiment of a local dimming controller and a light generation device;

Fig. 3 shows a diagram of another embodiment of a local dimming controller and a light generation device;

Figs. 4 - 7 show embodiments of data frames according to the present invention;

Fig. 8 shows an embodiment of a display device according to the present invention;

Fig. 9 shows a block diagram of another embodiment of a backlight system according to the present invention; and

Fig. 10 shows a flow diagram of an embodiment of a method according to the present invention.

[0032] In the figures like reference signs denote like elements unless stated otherwise.

DETAILED DESCRIPTION OF THE DRAWINGS

[0033] Fig. 1 shows a block diagram of an embodiment of a backlight system 1 with a current source 3 and a total of ten lighting units 7 to 16, which are configured as stripes, each with 30 LEDs 101 to 400 as light generation devices. The lighting units 7 to 16 connect to the current source 3 via power lines 65, 66.

[0034] In one embodiment, a video processor (not shown) of the respective display device 2 (see Fig. 8) analyses the video, which is displayed on the display device 2 to generate the local dimming information 6, and provides said local dimming information 6 to the current modulator 5.

[0035] The local dimming information 6 can e.g. provide information to set LEDs 101 to 400 in a specific zone 46 to 48 (see Fig. 8) of the display device 2 to a low brightness, if the video content in that zone is dark. Especially when turning off the LEDs a very good reproduction of black can be achieved. Furthermore, the local dimming information 6 can also comprise specific very high brightness settings for LEDs 101 to 400 in a specific zone 46 to 48, if this is required e.g. by High Dynamic Range, HDR, content.

[0036] The 30 LEDs 101 to 400 of each of the lighting units 7 to 16 are connected electrically in series. Furthermore, a local dimming controller 401 - 700 is provided for every single LED 101 to 400. The local dimming controllers 401 - 700 are configured to dim the respective LEDs according to the local dimming information 6. To receive the local dimming information 6, the local dimming controllers 401 - 700 demodulate the driving current 4. Accordingly, in the current source 3 a current modulator 5 modulates the driving current 4 according to the local dimming information 6.

[0037] The current modulator 5 can e.g. superimpose a modulated current signal comprising the local dimming information 6 over the driving current 4. The superimposed modulated signal can have an amplitude, which is smaller than the amplitude of the driving current 4. The amplitude of the superimposed modulated signal can e.g. be such that the modulation does not produce any visible effects in the brightness of the LEDs 101 - 400. Furthermore, the duration of a data frame 26, 30, 34, 45 (see Figs. 4 - 7) can be considerably shorter than the period of the frequency, with which images are displayed on the display device 2, e.g. 100Hz, 200Hz, or 400Hz.

[0038] The current modulator 5 uses a Manchester based encoding scheme for modulating the local dimming information 6. The selection of this encoding scheme is just exemplary. It is to be understood, that any other adequate modulation scheme can be used by the modulator.

[0039] When a local dimming controller 401 - 700 decodes the encoded local dimming information 6 from the driving current 4, the local dimming controller 401 - 700 determines if the LED 101 - 400, which is controlled by the respective local dimming controller 401 - 700 has to be dimmed. If not, the local dimming controller 401 - 700 will continue to drive the respective LED 101 - 400 with an unmodified brightness. However, if the respective LED 101 - 400 is affected by the local dimming information 6, the local dimming controller 401 - 700 will adapt the brightness of the respective LED 101 - 400 accordingly. For a more detailed explanation on how the local dimming information 6 is transmitted, reference is made to Figs. 4 to 8.

[0040] The number of lighting units 7 - 16 and the number of LEDs 101 - 400 on every lighting unit 7 - 16 is an arbitrary choice, which leads to a total of three hundred LEDs 101 - 400. It is to be understood, that the number of LEDs 101 - 400 per lighting unit 7 - 16 and the number of lighting units 7 - 16 can be varied according to different application's demands.

[0041] Furthermore, in other embodiments a single local dimming controller 401 - 700 can control more than one LED 101 - 400. A local dimming controller 401 - 700 can e.g. control all LEDs 101 - 400 of a lighting unit 7 - 16, or two LEDs 101 - 400 right next to him.

[0042] In Fig. 2 a light generation device 17 and a local dimming controller 18 are provided on a carrier board 60, e.g. a printed circuit board 60, next to each other.

[0043] Traces 62 connect the local dimming controller 18 either to the current source (not shown) or to further local dimming controllers (not shown), connected in series to the local dimming controller 18, depending on whether the local dimming controller 18 is the first or a further dimming controller of a lighting unit 7 - 16.

[0044] The local dimming controller 18 decodes the local dimming information 6, which is transmitted in the driving current 4, and via traces 61 controls the LED 17 to shine with the brightness indicated in the local dimming information 6.

[0045] Fig. 3 shows an alternative configuration of the light generation device 17 and the local dimming controller 18. While the light generation device 17 and the local dimming controller 18 are the same, as in Fig. 2, they are not positioned next to each other. Instead, the light generation device 17 and the local dimming controller 18 are positioned on top of each other in a common housing 19.

[0046] This configuration safes space on the carrier board 60, and therefore allows providing more LEDs 101 - 400 on the same space. Furthermore, the production of the local dimming controller 17 and the LED 18, which are both semiconductor devices, can be performed in a single semiconductor production process. Finally, the mounting of the lighting units 7 - 16 is also simplified, because only one device has to be soldered onto the carrier board 60 for every LED 101 - 400.

[0047] In Fig. 3 the internals of the local dimming controller 18 are displayed in greater detail. A current sensor 20 is provided, e.g. a shunt resistance, which senses the driving current 4 together with the superimposed local dimming information 6. The sensed current is demodulated by the demodulator 21, which can e.g. comprise a high-pass filter, which will filter out the driving current 4 and only pass through the modulated local dimming information 6. A respective demodulation logic can then provide the content of the local dimming information 6 to the protocol engine 22. The protocol engine 22 analyses the local dimming information according to a predefined protocol and provides dimming settings for the LED 17 to a Pulse-Width-Modulator 24, or PWM-Modulator, which dims the LED17 accordingly. Figs. 4 to 7 show examples of a possible protocol.

[0048] The local dimming controller 18 further comprises a memory 25, which stores the membership of the LED 17 to different zones 46 - 48. Therefore, the protocol engine 22 will only adapt the brightness of the LED 17, if the LED is directly addressed or belongs to a zone 46 - 48, which is addressed in a data frame.

[0049] Fig. 4 shows a data frame 26, which comprises three different sections. The first section 42 comprises a command indicator with the binary value of "11". This command indicator 42 indicates that the following data section comprises the address of a single LED 101 to 400. In this case the LED 101 to 400 with the binary address "1100100", decimal 100, is addressed. The command indicator 42 further indicates that the second data section comprises a brightness value 28, in this case binary "10000000", decimal 128, or half of the value range of one byte.

[0050] The command "11" can therefore be used to address a single LED 101 to 400 of the backlight system 1. If more than one LED 101 to 400 has to be addressed, this can be performed by sequentially addressing single LEDs 101 to 400. Alternatively, groups of LEDs 101 to 400 can be addressed by zones 46 to 48.

[0051] Fig. 5 shows a data frame 30, which comprises the command indicator 43 with the binary value of "01". This command indicator 43 shows the local dimming controllers 18, 401 to 700 that the following data section comprises the identification for a predefined active zone 33 of the display device 2. In this case, the zone with the binary identification "1100100", decimal 100, is addressed. Consequently, the brightness value 31 of binary "10000000", decimal 128, is set for all LEDs 101 to 400 belonging to zone 100.

[0052] The above command "01" works very well to address LEDs 101 to 400 of predefined groups. Nevertheless, if none of the zones 46 to 48 match the actual dimming requirements, the command "10" shown in Fig. 6 can be used.

[0053] The data frame 34 in Fig. 6 comprises the command indicator 44 with the value of "10". This command indicator 44 indicates to the local dimming controllers 18, 401 - 700 that the following data section comprises identifications for two LEDs, the upmost left LED of a square shaped zone 46 to 48 and the lowest right LED of the zone 46 to 48. The two identifications 35, 36 therefore identify the corners of the respective zone 46 to 48. In Fig. 6 a zone is defined from the upmost left LED of a screen, X=0, Y=0, to the twenty-eighth LED in the eighth row, X=28, Y=8. This scheme assumes that the upmost left LED has the coordinates 0, 0 and the first coordinate is the abscissa and the second coordinate is the ordinate.

[0054] Furthermore, the brightness value 41 with the value of 128 is transmitted in the last data section.

[0055] The local dimming controllers 18; 401 to 700 in the above example will determine, if their LED 17, 101 to 400 is within the coordinates, i.e. if 0 <= X-coordinate of LED <= 28, and if 0 <= Y-coordinate of LED <= 8. Only those LEDs 17, 101 to 400 will be dimmed accordingly, which are within this zone 46 to 48.

[0056] The local dimming controllers 18, 401 to 700 can store the zone 46 to 48 defined in a data frame with the "10" command indicator 44. For this purpose a data section with an identifier for the newly created group can be included in the data frame. The newly created zone 46 to 48 can then be addressed e.g. as explained with regard to Fig. 5.

[0057] It is to be understood, that the command indicators 42, 43, and 44 are mere examples and any other scheme can be used to identify the content of a data frame.

[0058] Fig. 7 shows a diagram of a driving current 4 with an embedded data frame 45. Furthermore, the period 47 of the frequency with which images are displayed on the display device 2 is shown. It can be seen, that the data frame 45 is about $1/5^{th}$ of the period 47. This ensures that no brightness variations will be perceptible to the human eye during a frame.

[0059] Furthermore, it can be seen, that the data of the data frame 45 is modulated onto the driving current 4 by reducing the driving current 4 according to a predefined modulation scheme. In such a scheme binary 0 and 1 can e.g. be differentiated by the duration of the reduction of the driving current 4.

[0060] It is to be understood, that this reduction of the driving current 4 is just exemplarily and a bi-polar modulation could also be used, in which a positive addition to the driving current 4 denotes a binary 1 and a negative subtraction from the driving current 4 denotes a binary 0, or vice versa.

[0061] Fig. 8 shows a display device 2. In the display device 2 three zones 46 to 48 are shown just as an example.

[0062] It can be seen, that the creation of arbitrary and especially overlapping zones becomes possible with the present invention. Especially, with the command indicator 44 with the binary value "10" it is possible to define any rectangular zone 46 to 48.

[0063] Further command indicators can be provided, which e.g. allow defining zones of other shapes, like e.g. triangular zones, pentagonal zones, hexagonal zones, end the like. Furthermore, command indicators can be defined, which define a specific brightness curve, like e.g. a Gaussian curve or a saw-tooth shaped curve.

[0064] The backlight system 1000 of Fig. 9 comprises a power board 1000A. In the power board a switch mode power supply 1001 supplies the required electrical power to a global dimming module 1002. The global dimming module 1002 is a current source for the LEDs 1004 and 1006 and has a current limiting capability for globally dimming the LEDs 1004 and 1006. According to the present invention the global dimming module 1002 further is a current modulator.

[0065] Just as an example to explain the addressing of the single LEDs 1004, 1006 a LED bar 1000B with the LEDs 1004 and 1006 is shown. It is understood, that further LED bars are possible. The LED bar 1000B provides for every LED 1004, 1006 a respective local dimming controller 1003, 1005. Various other connection schemes between the LEDs 1004, 1006 and the controllers 1003, 1005 are also possible.

[0066] The controller 1003 and the LED 1004 in the exemplary structure of Fig. 9 are identified as group 1 which has a binary address value of 000110. Controller 1005 and LED 1006 are identified as group 2, respectively, which has a binary address value of 000111.

[0067] If a data frame is transmitted to the controller 1003, which includes the address 000110 the controller 1003 will demodulate the respective information and control the LED 1004 accordingly. On the other hand, if a data frame is transmitted to controller 1003, which includes the address 000111 the controller 1003 will ignore the data frame. However, controller 1005 will demodulate the information in this data frame and control LED 1006 accordingly.

[0068] In Fig. 9 an exemplary addressing scheme is shown. It is to be understood, that other alternative addressing schemes are also possible.

[0069] The method of Fig. 10 starts in step S1 with providing a driving current 4 from a current source 3, 1001 to a number of lighting units 7 - 16, 1000B connected to the current source 3, 1001 and comprising a plurality of light generation devices 17; 101 - 400, 1004, 1006 connected electrically in series. The lighting units 7 - 16, 1000B in contrast are connected electrically in parallel to the current source 3.

[0070] In step S2 the driving current 4 is modulated according to local diming information 6, and finally in steps S3 the light generation devices 17; 101 - 400, 1004, 1006 are dimmed according to the local diming information 6 provided in the driving current 4 with a number of local dimming controllers 18; 401 - 700, 1003, 1005 in each lighting unit 7 - 16, 1000B.

[0071] In order to dim, S3, the light generation devices 17; 101 - 400, 1004, 1006 in the local dimming controllers 18; 401 - 700, 1003, 1005 the driving current 4 is sensed, and the local dimming information is demodulated from the sensed driving current 4. From the local dimming information the respective dimming settings 23 for the light generation devices 17; 101 - 400, 1004, 1006 connected to the respective local dimming controller 18; 401 - 700, 1003, 1005 are derived.

[0072] When modulating, S2, the driving current 4, data frames 26; 30; 34; 45 are provided in the driving current 4, which are shorter than half the period 27, especially a fourth of the period 27 or a fifth of the period 27, of the display frequency, with which images are displayed on the display device 2. In a data frame 26; 30; 34; 45 an address 29 of a light generation device 17; 101 - 400, 1004, 1006 and a respective brightness value 28; 31; 41 can be provided. In other data frames 26; 30; 34; 45 a zone setting command for setting up a new zone 46 - 48, the identification 35 of an upper left light generation device 17; 101 - 400, 1004, 1006 of the zone 46 - 48, and the identification 36 of a lower right light generation device 17; 101 - 400, 1004, 1006 of the new zone 46 - 48 is provided.

[0073] The identification 35, 36 of a light generation device 17; 101 - 400, 1004, 1006 can comprise two coordinates 37 - 40 of the light generation device 17; 101 - 400, 1004, 1006 in Cartesian coordinates. In this case when modulating, S2, the driving current 4 a light generation device 17; 101 - 400, 1004, 1006 is identified as belonging to the new zone 46 - 48, if the values of the two coordinates of the respective light generation device 17; 101 - 400, 1004, 1006 are between the values of the coordinates 37, 38 of the upper left light generation device 17; 101 - 400, 1004, 1006 and the values of the coordinates 39, 40 of the lower right light generation device 17; 101 - 400, 1004, 1006 of the new zone 46 - 48.

[0074] Although specific embodiments have been illustrated and described herein, it will be appreciated by those of ordinary skill in the art that a variety of alternate and/or equivalent implementations exist. It should be appreciated that the exemplary embodiment or exemplary embodiments are only examples, and are not intended to limit the scope, applicability, or configuration in any way. Rather, the foregoing summary and detailed description will provide those skilled in the art with a convenient road map for implementing at least one exemplary embodiment, it being understood that various changes may be made in the function and arrangement of elements described in an exemplary embodiment without departing from the scope as set forth in the appended claims and their legal equivalents. Generally, this application is intended to cover any adaptations or variations of the specific embodiments discussed herein.

[0075] Thus, the present invention provides a backlight system 1 for a display device 2, comprising a current source 3, 1001 configured to provide a driving current 4, a number of lighting units 7 - 16, 1000B connected to the current source 3, 1001 and comprising a plurality of light generation devices 17; 101 - 400, 1004, 1006 connected electrically in series, wherein the lighting units 7 - 16, 1000B are connected electrically in parallel to the current source 3, at least one current modulator 5, 1002 configured to modulate the driving current 4 according to local diming information 6, and a number of local dimming controllers 18; 401 - 700, 1003, 1005 for each lighting unit 7 - 16, 1000B, the local diming controllers being connected to a number light generation devices 17; 101 - 400, 1004, 1006 of the respective lighting unit 7 - 16, 1000B and being configured to dim the respective light generation devices 17; 101 - 400, 1004, 1006 according to the local diming information 6 provided in the driving current 4. Furthermore, the present invention provides a respective method for controlling a backlight system 1, 1000.

List of reference signs

1, 1000	backlight system
2	display device
3, 1001	current source
4	driving current
5, 1002	current modulator
6	local diming information
7 - 16, 1000B	lighting units
17; 101 - 400, 1004, 1006	light generation devices

(continued)

18; 401 - 700, 1003, 1005	local dimming controllers
19	housing
20	current sensor
21	demodulator
22	protocol engine
23	dimming settings
24	PWM-Modulator
25	memory
26; 30; 34; 45	data frame
27	period
28; 31; 41	brightness value
29	address
33; 35, 36	identification
37 - 40	coordinates
42, 43, 44	command indicator
46 - 48	zones
49	carrier
60	carrier board
61, 62	traces
65, 66	power lines
1000A	power board

Claims

1. Backlight system (1, 1000) for a display device (2), comprising:

a current source (3, 1001) configured to provide a driving current (4),
a number of lighting units (7 - 16, 1000B) connected to the current source (3, 1001) and comprising a plurality of light generation devices (17; 101 - 400, 1004, 1006) connected electrically in series, wherein the lighting units (7 - 16, 1000B) are connected electrically in parallel to the current source (3, 1001),
at least one current modulator (5, 1002) configured to modulate the driving current (4) according to local diming information (6), and
a number of local dimming controllers (18; 401 - 700, 1003, 1005) for each lighting unit (7 - 16, 1000B), the local diming controllers being connected to a number light generation devices (17; 101 - 400, 1004, 1006) of the respective lighting unit (7 - 16, 1000B) and being configured to dim the respective light generation devices (17; 101 - 400, 1004, 1006) according to the local diming information (6) provided in the driving current (4).

2. Backlight system (1, 1000) according to claim 1, wherein one local dimming controller (18; 401 - 700, 1003, 1005) is provided for every light generation device (17; 101 - 400, 1004, 1006), and especially wherein the local dimming controller (18; 401 - 700, 1003, 1005) is integrated in the housing (19) of the respective light generation device (17; 101 - 400, 1004, 1006).

3. Backlight system (1, 1000) according to any one of the preceding claims, wherein the local dimming controllers (18; 401 - 700, 1003, 1005) comprise a current sensor (20) for sensing the driving current (4), a demodulator (21), which demodulates the local dimming information from the sensed driving current (4), and a protocol engine (22), which derives from the local dimming information the respective dimming settings (23) for the light generation devices (17; 101 - 400, 1004, 1006) connected to the respective local dimming controller (18; 401 - 700, 1003, 1005).

4. Backlight system (1, 1000) according to any one of the preceding claims, wherein the current modulator (5, 1002) is configured to provide data frames (26; 30; 34; 45) in the driving current (4), which are shorter than half the period (27), especially a fourth of the period (27) or a fifth of the period (27), of the display frequency, with which images are displayed on the display device (2).

5. Backlight system (1, 1000) according to any one of the preceding claims, wherein the current modulator (5, 1002) is configured to provide in a data frame (26; 30; 34; 45) an address (29) of a light generation device (17; 101 - 400, 1004, 1006) and a respective brightness value (28; 31; 41).

6. Backlight system (1, 1000) according to any one of the preceding claims, wherein the current modulator (5, 1002) is configured to provide in a data frame (26; 30; 34; 45) an identification (33) of an active zone (46 - 48) and a respective brightness value (28; 31; 41).

7. Backlight system (1, 1000) according to claim 6, wherein the local dimming controllers (18; 401 - 700, 1003, 1005) comprise a memory (25), storing for every connected light generation device (17; 101 - 400, 1004, 1006), the active zones (46 - 48) to which the respective light generation device (17; 101 - 400, 1004, 1006) belongs.

8. Backlight system (1, 1000) according to any one of claims 6 and 7, wherein the current modulator (5, 1002) is configured to provide in a number of data frames (26; 30; 34; 45) a zone setting command for setting up a new zone (46 - 48), the identification (35) of an upper left light generation device (17; 101 - 400, 1004, 1006) of the zone (46 - 48), and the identification (36) of a lower right light generation device (17; 101 - 400, 1004, 1006) of the new zone (46 - 48).

9. Backlight system (1, 1000) according to claim 8, wherein the identification (35,36) of a light generation device (17; 101 - 400, 1004, 1006) comprises two coordinates (37 - 40) of the light generation device (17; 101 - 400, 1004, 1006) in Cartesian coordinates, and wherein the local dimming controllers (18; 401 - 700, 1003, 1005) are configured to identify a light generation device (17; 101 - 400, 1004, 1006) belonging to the new zone (46 - 48), if the values of the two coordinates of the respective light generation device (17; 101 - 400, 1004, 1006) are between the values of the coordinates (37, 38) of the upper left light generation device (17; 101 - 400, 1004, 1006), and the values of the coordinates (39, 40) of the lower right light generation device (17; 101 - 400, 1004, 1006) of the new zone (46 - 48).

10. Method for controlling a backlight system (1, 1000) for a display device (2), comprising the steps:

providing (S1) a driving current (4) from a current source (3, 1001) to a number of lighting units (7 - 16, 1000B) connected to the current source (3, 1001) and comprising a plurality of light generation devices (17; 101 - 400, 1004, 1006) connected electrically in series, wherein the lighting units (7 - 16, 1000B) are connected electrically in parallel to the current source (3, 1001),
modulating (S2) the driving current (4) according to local diming information (6), and
dimming (S3) the light generation devices (17; 101 - 400, 1004, 1006) according to the local diming information (6) provided in the driving current (4) with a number of local dimming controllers (18; 401 - 700, 1003, 1005) in each lighting unit (7 - 16, 1000B).

11. Method according to claim 10, wherein in the local dimming controllers (18; 401 - 700, 1003, 1005) the driving current (4) is sensed, the local dimming information is demodulated from the sensed driving current (4), and from the local dimming information the respective dimming settings (23) for the light generation devices (17; 101 - 400, 1004, 1006) connected to the respective local dimming controller (18; 401 - 700, 1003, 1005) are derived.

12. Method according to any one of the preceding claims 10 and 11, wherein when modulating the driving current (4) data frames (26; 30; 34; 45) are provided in the driving current (4), which are shorter than half the period (27), especially a fourth of the period (27) or a fifth of the period (27), of the display frequency, with which images are displayed on the display device (2).

13. Method according to any one of the preceding claims 10 to 12, wherein when modulating the driving current (4) in a data frame (26; 30; 34; 45) an address (29) of a light generation device (17; 101 - 400, 1004, 1006) and a respective brightness value (28; 31; 41) are provided.

14. Method according to any one of the preceding claims 10 to 13, wherein when modulating the driving current (4) in a number of data frames (26; 30; 34; 45) a zone setting command for setting up a new zone (46 - 48), the identification (35) of an upper left light generation device (17; 101 - 400, 1004, 1006) of the zone (46 - 48), and the identification (36) of a lower right light generation device (17; 101 - 400, 1004, 1006) of the new zone (46 - 48) is provided.

15. Method according to claim 14, wherein the identification (35, 36) of a light generation device (17; 101 - 400, 1004, 1006) comprises two coordinates (37 - 40) of the light generation device (17; 101 - 400, 1004, 1006) in Cartesian

coordinates, and wherein when modulating the driving current (4) a light generation device (17; 101 - 400, 1004, 1006) is identified as belonging to the new zone (46 - 48), if the values of the two coordinates of the respective light generation device (17; 101 - 400, 1004, 1006) are between the values of the coordinates (37, 38) of the upper left light generation device (17; 101 - 400, 1004, 1006) and the values of the coordinates (39, 40) of the lower right light generation device (17; 101 - 400, 1004, 1006) of the new zone (46 - 48).

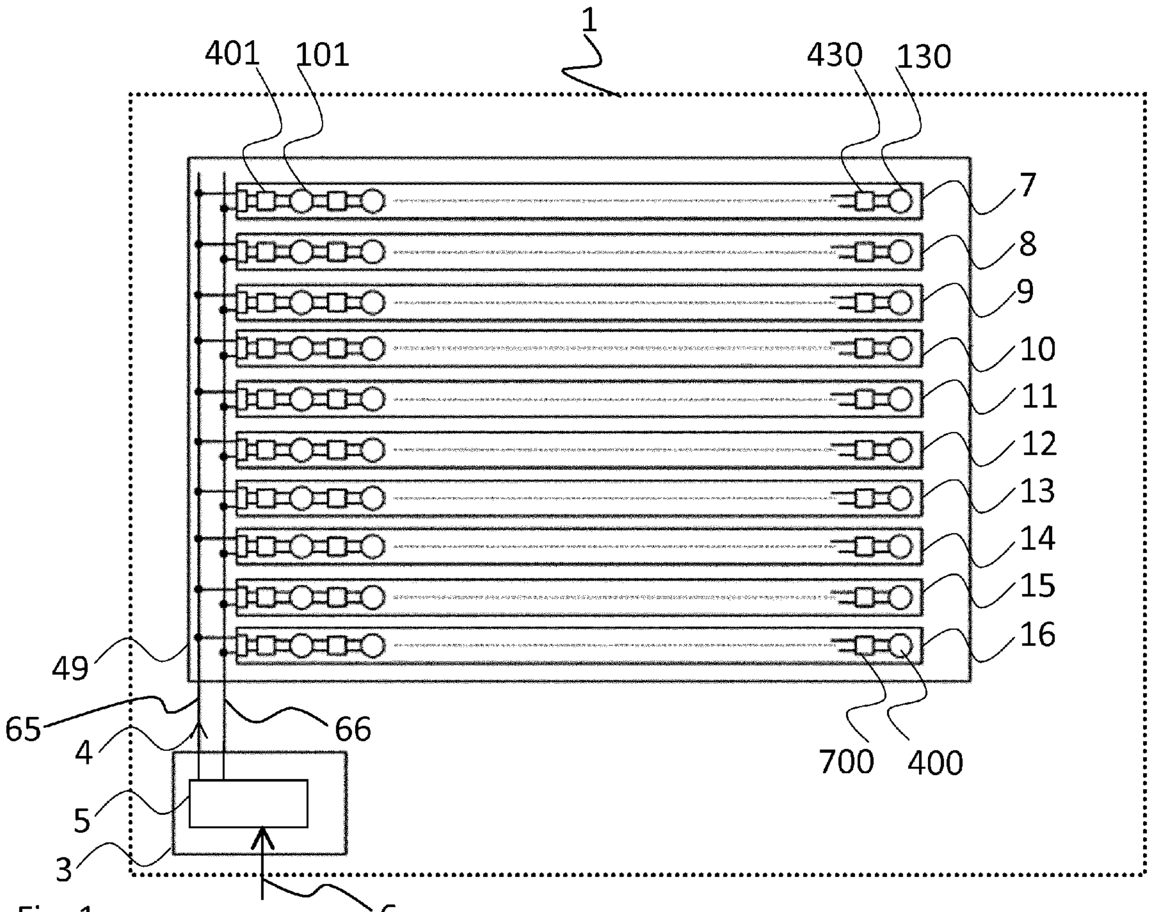

Fig. 1

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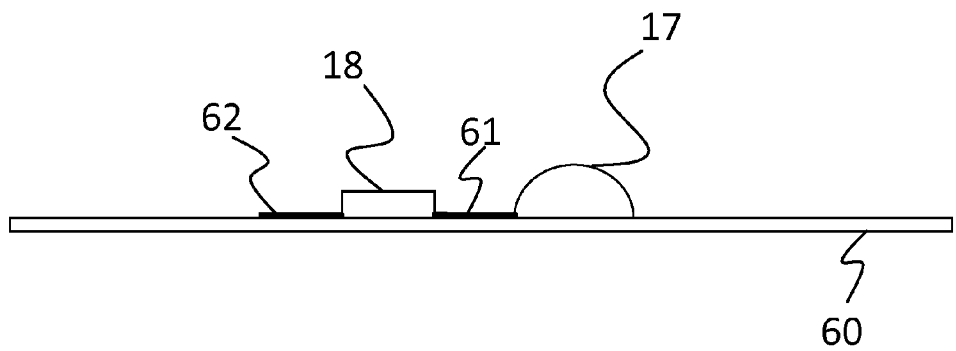
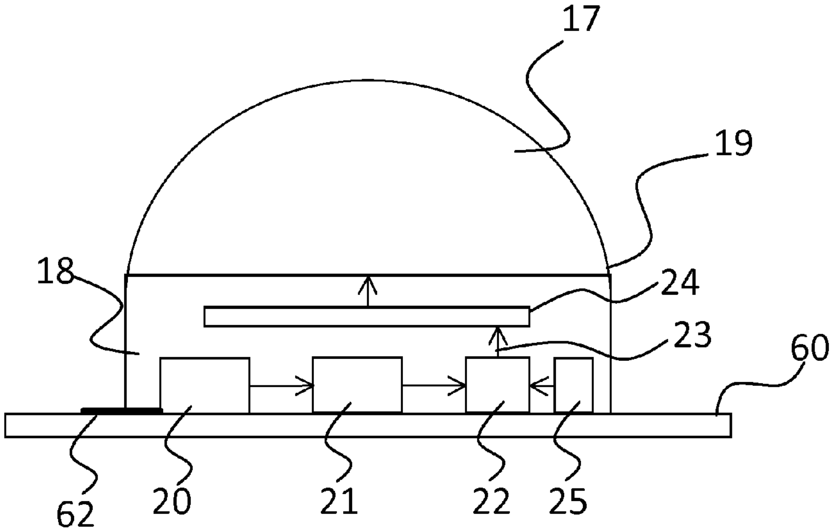


Fig. 2



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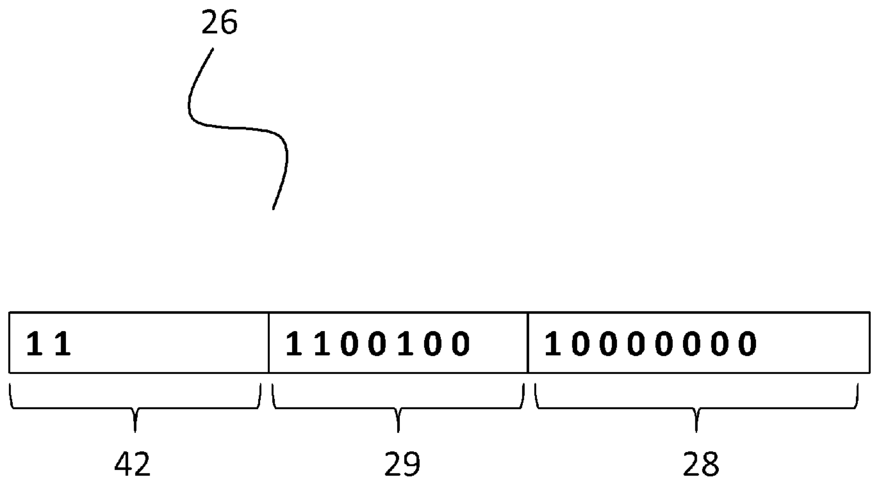


Fig. 4

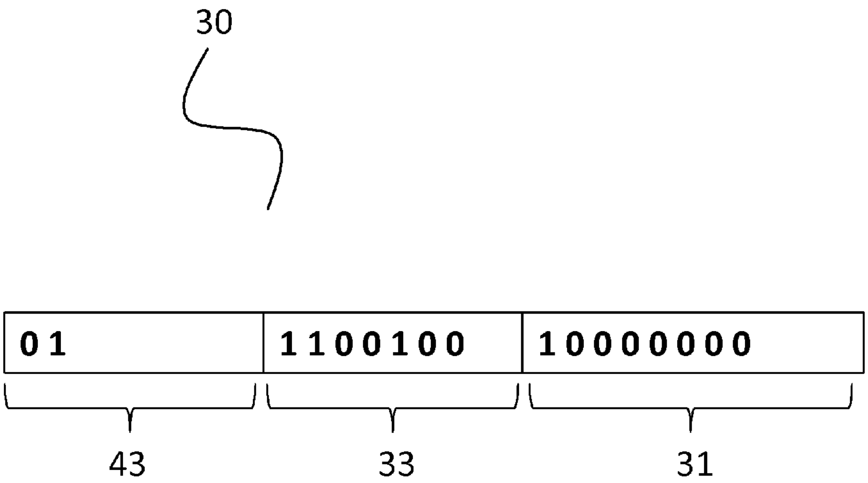


Fig. 5

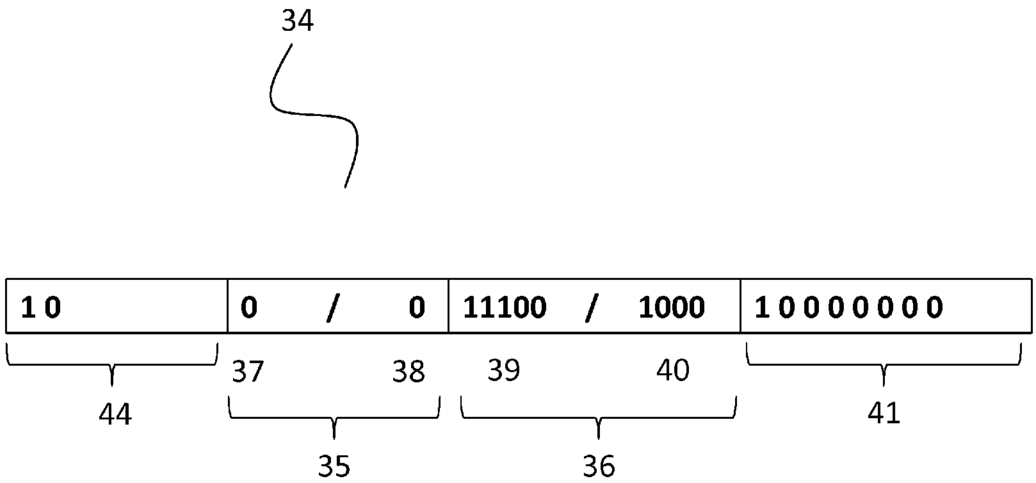


Fig. 6

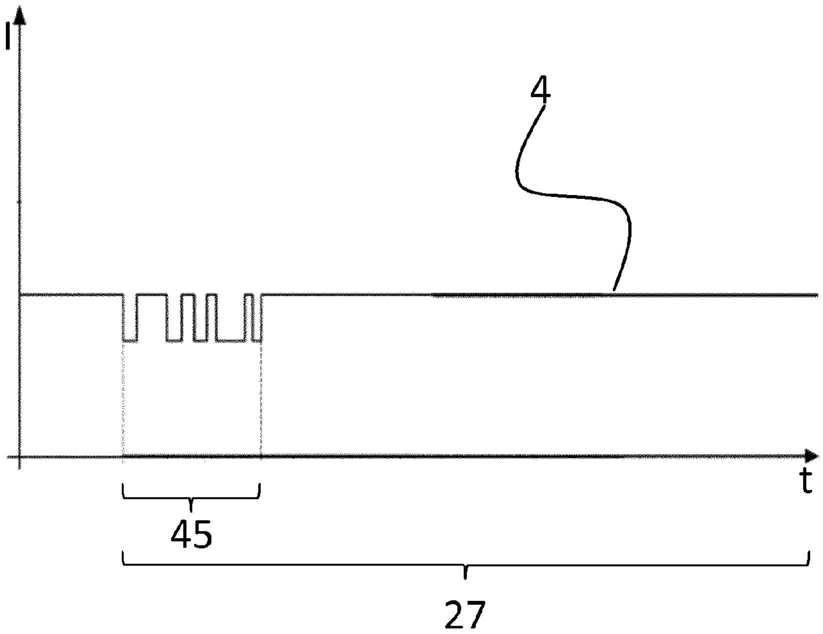


Fig. 7

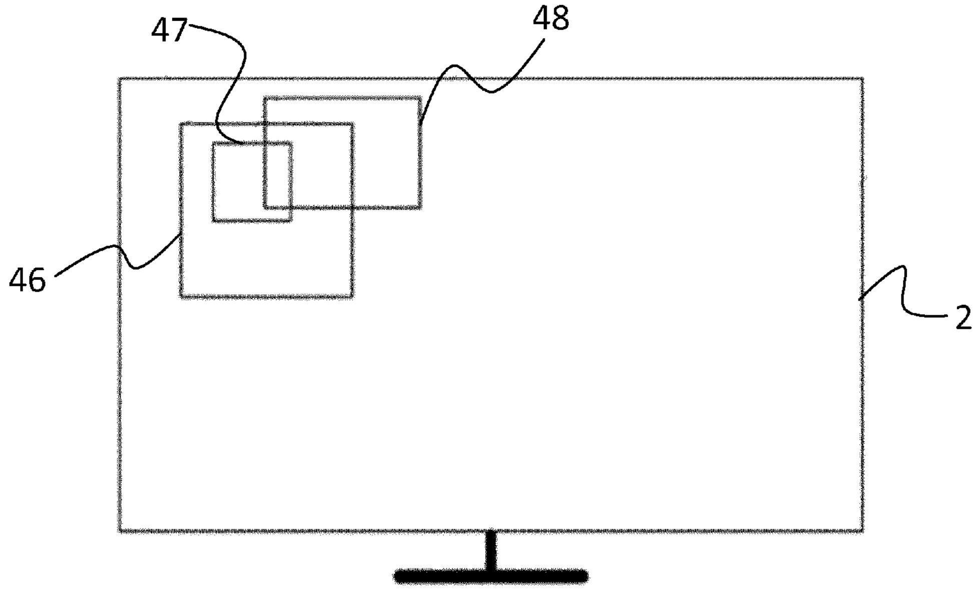
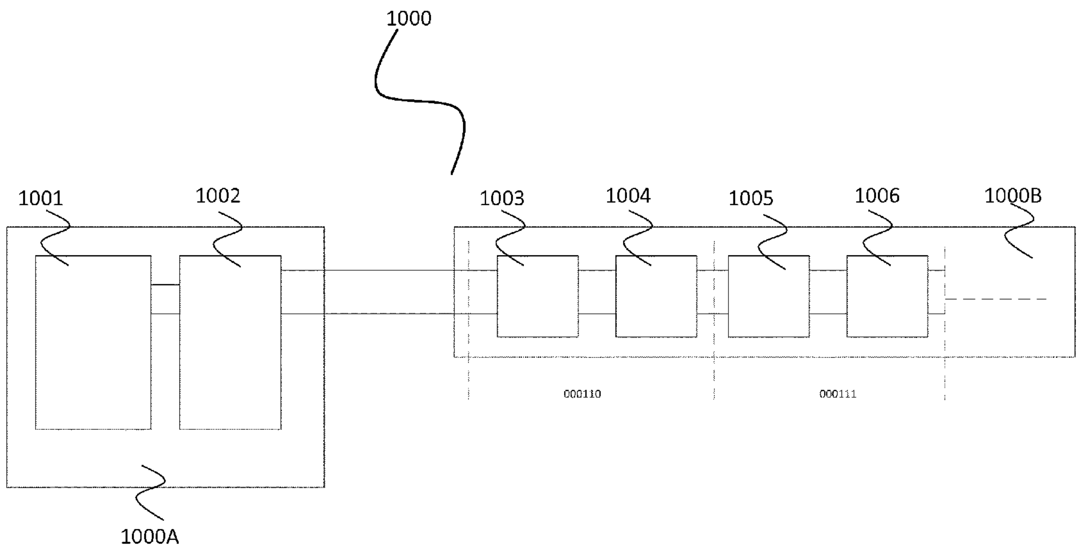


Fig. 8


1000
1001
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1003
1004
1005
1006
1000B
000110
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Fig. 9

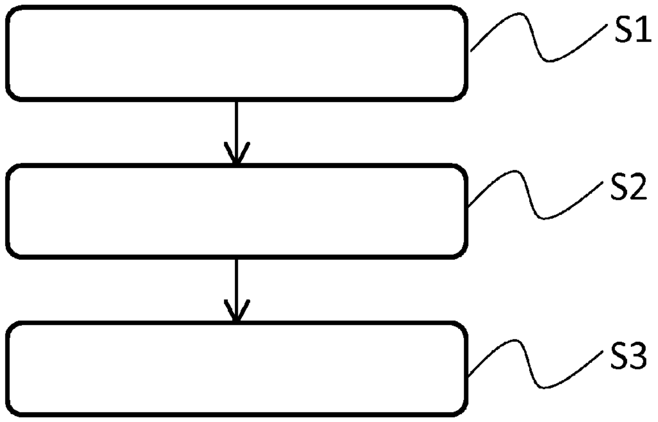

Fig. 10

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EUROPEAN SEARCH REPORT

Application Number
EP 15 19 7331

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	US 2013/285553 A1 (SHIMOMURA TSUTOMU [US] ET AL) 31 October 2013 (2013-10-31) * paragraph [0039] - paragraph [0062]; figures 1-4 * -----	1-15	INV. G09G3/34
			TECHNICAL FIELDS SEARCHED (IPC)
			G09G

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
The Hague	12 May 2016	Fanning, Neil

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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12-05-2016

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