DISPLAY DEVICE AND A METHOD OF CONTROLLING A DISPLAY DEVICE

A display device is provided which comprises a control panel for displaying a video signal, a backlight unit (BLU) for backlighting the display panel (PU) having a plurality of strings of light emitting devices (LED1 - LED3) for emitting light. The display device furthermore comprises at least one sensor unit (SU) for detecting the light emitted by the strings of light emitting devices (LED1 - LED3). The backlight unit (BLU) furthermore comprises a plurality of driver units (DU1 - DU3) each for driving a string of light emitting devices (LED1 - LED3), a control unit (CU) for controlling each of the plurality of driver units (DU1 - DU3) and a calibration unit (C) for receiving the output signal of the sensor units (SU) and for providing calibration information to the control unit (CU). Each driver unit (DU1 - DU3) comprises a modulation pattern unit (MPU) for providing a modulation pattern at a multiple of the frequency of the output signal from the control unit (CU) and a mixing unit (MU) for mixing a frequency multiplied control signal from the control unit (CU) with the modulation pattern. The output signal of the mixing unit (MU) is applied to one of the strings of light emitting devices (LED1 - LED3). The control unit (CU) is provided to adapt the controlling of the plurality of driver units (DU1 - DU3) based on the calibration information from the calibration unit (CU). The sensor unit (SU) is adapted to detect the modulation pattern in the light emitted by the strings of light emitting devices (LED1 - LED3) and to forward the detected modulation pattern to the calibration unit (C).
FIELD OF THE INVENTION

The present invention relates to a display device and a method of controlling a display device.

BACKGROUND OF THE INVENTION

Modern televisions are typically liquid crystal display LCD televisions. To improve the performance of these televisions, backlighting has been introduced. Apart from cold cathode fluorescent light CCFL technology as backlight, the backlighting can also be performed based on LED technology.

However, one challenge of using LED as backlight is to ensure a uniform white matrix of the backlight. Due to process variations, the LED will have differences in their luminous output and colour. To ensure the uniformly white matrix of the backlight, a control system is required. This can for example be performed by means of a constant current or by means of pulse width modulation PWM control. It should be noted that a change in the current through the LED will result to a different colour of the LED. Accordingly, the LED are driven by a pulse width modulated PWM constant current. In the prior art systems, several methods to calibrate the LED of the backlight are known dealing with temperature drift and aging effects.

The calibration can be performed by measuring the light of each LED or each LED segment. Accordingly, a sensor must be provided for each of the segments. This method is, however, disadvantageous as it requires a great amount of sensors for detecting light. In addition, it is very hard to calibrate the uniformity while the user is watching TV, because the flashing patterns that usually are required to calibrate the backlight will distract from the viewing experience.
According to a further calibration method of the prior art, the dead time in the PWM is used. However, it should be noted that this calibration method requires a very sensitive and fast sensor with sample & hold circuitry that will be expensive to produce.

A further calibration method relates to the use of a PWM skipping calibration. Here, the luminescence of a LED segment is only measured for a very short period of time. However, this method results as well in flickering patterns on the screen, so that it can not be performed while the user is watching TV.

What is required is a calibration method that can be executed while the user is watching TV, without generating distracting patterns or visible artifacts.

SUMMARY OF THE INVENTION

It is an object of the invention to provide a display device which enables a calibration during its operation which cannot be perceived by a user of the display device.

This object is solved by a display device according to claim 1 and a method of controlling a display device according to claim 8.

Therefore, a display device is provided which comprises a control panel for displaying a video signal, a backlight unit for backlighting the display panel having a plurality of strings of light emitting devices for emitting light. The display device furthermore comprises at least one sensor unit for detecting the light emitted by the strings of light emitting devices. The backlight unit furthermore comprises a plurality of driver units each for driving a string of light emitting devices, a control unit for controlling each of the plurality of driver units and a calibration unit for receiving the output signal of the sensor units and for providing calibration information to the control unit. Each driver unit comprises a modulation pattern unit for providing a modulation pattern at a multiple of the frequency of the output signal from the control unit and a mixing unit for mixing a frequency multiplied control signal from the control unit with the modulation pattern. The output signal of the mixing unit is applied to one of the strings of light emitting devices. The control unit is provided to adapt the controlling of the plurality of driver units based on the calibration information from the calibration unit. The sensor unit is adapted to detect
the modulation pattern in the light emitted by the strings of light emitting devices and
forward the detected modulation pattern to the calibration unit.

The display device according to the invention is advantageous as a
calibration can be performed for example continuously without any viewer noticing or
perceiving the calibration pattern in the video signal.

According to an aspect of the invention, the sensor unit comprises a
filter for the modulation pattern in the light emitted by the strings of light emitting
devices. Accordingly, only the modulation pattern or the calibration pattern is
detected by the sensor unit and the other signals can be filtered out.

According to a further aspect of the invention, each driver unit
comprises a pulse width modulation unit for performing a pulse width modulation
based on a summation of the frequency multiplied output signal from the control unit
and the modulation pattern from the modulation pattern unit. In other words, the
PWM signal is modulated based on the modulation pattern.

The invention relates to the idea to provide an oversampling LED
driver for driving strings of LEDs. From this multi-channel oversampling LED driver,
it should be possible to switch the oversampling feature on or off per individual
output. In oversampling mode, the driver generates multiple output values for each
single input value.(by repeating the input value on a higher frequency) By adding or
multiplying patterns on top of the "normal" oversampled luminescence control values
which are delivered to the LED drivers and by detecting these patterns, a calibration
of the strings of LEDs can be performed.

Accordingly, the uniformity of the backlighting can be calibrated using
an oversampling driver and special patterns which are superimposed over the normal
control signals while a user is watching the TV.

Further aspects of the invention are defined in the dependent claims.

BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments and advantages of the invention will now be described in
more detail with reference to the Figures.

Fig. 1 shows a block diagram of a display unit according to a first
embodiment,
Fig. 2A shows a PWM pattern according to the first embodiment,
Fig. 2B shows a block diagram of a driver unit according to the second embodiment,
Fig. 3 shows a schematic block diagram of parts of a display device according to a third embodiment,
Fig. 4 shows a graph of the PWM modulation spectrum at 240 Hz,
Fig. 5 shows a graph of the modulation spectrum according to the invention,
Fig. 6 shows a graph of a modulation spectrum according to a fourth embodiment, and
Fig. 7 shows a basic representation of a display device according to a fifth embodiment.

DETAILED DESCRIPTION OF EMBODIMENTS

Fig. 1 shows a block diagram of a display unit according to a first embodiment. The display device comprises a LED panel PU, a backlight unit BLU and a sensor unit SU. The backlight unit BLU comprises a plurality of strings of LEDs LED1 - LED3 for emitting light, which are each coupled to a driver unit DU1 - DU3 serving to drive the respective strings of LEDs. The driver units DU1 - DU3 are each coupled to a controller unit CU, which provides the respective driving information S1 - S3 to the drivers DU1 - DU3. The driving information S1 - S3 will comprise pulse width modulation PWM values, which enable the driver unit DU1, DU3 to drive the respective strings of LEDs LED1 - LED3 accordingly. The backlight unit BLU can furthermore optionally comprise a calibration unit C which receives the output of the sensor unit SU detecting the light emission of the backlight unit BLU. The information from the sensor unit SU can be used in the calibration unit C to calibrate the respective strings of LEDs LED1 - LED3. In particular, the calibration unit C can determine the amount of calibration or adjustment which is required for each of the strings of LEDs LED1 - LED3. This calibration or adjustment information can be used by the controller unit CU to control the respective driving unit DU1 - DU3 to adapt the driving signals for the respective strings of LEDs LED1 - LED3 accordingly.
Fig. 2A shows a graph depicting the PWM performed by a driver unit according to a second embodiment. Fig. 2B shows a block diagram of a driver unit according to a second embodiment. The driver unit according to the second embodiment can be used in the backlight unit BLU according to the first embodiment.

In Fig. 2A, the original PWM signal for example 240 Hz and the new PWM driver signal according to the second embodiment (for example with 1920 Hz) is depicted.

According to the second embodiment, the original PWM signal is multiplied for example eight times. However, it should be noted that also other multiplication rates are possible. The multiplication of the PWM rate is advantageous as a calibration signal at such a frequency would not be perceived by a viewer of a corresponding TV. According to the second embodiment, the control unit CU provides a PWM signal at a first frequency, for example 240 Hz, i.e. the input signal of the driver unit S1 - S3 is at a first frequency. However, the output O1 - O3 of the driver unit DU is at a second frequency which is a multiple of the first frequency. The driver unit DU comprises a modulation pattern unit MPU for providing a modulation pattern which is to be added onto the input signal (multiplied by multiplying unit MU). The modulation pattern as provided by the modulation pattern unit MPU and serves as calibration pattern. The driver unit DU can furthermore comprise a PWM output unit PWMO. As the calibration pattern is at a frequency which is not visible by a user, the user will not perceive any introduction of such a calibration pattern into the video signal.

As the driver unit DU is operated at a frequency which is much higher than required, the driver is used as an oversampling driver.

According to the second embodiment, the driver units DU1 - DU2 receive the input signals S1 - S3 from the calibration unit CU that can be updated at 240 Hz.

In order to improve the performance of the driver units DU1 - DU3, noise shaping techniques can be used. This can for example be performed by switching between PWM values above and beneath the required value. This is in particular advantageous as the resolution in the PWM dimming depth can be maintained. This noise shaping technique can for example be applied if the PWM
input value corresponds to 7.5. In such a case, the output of the driver units may alternate between 7 and 8. Due to the fact that the output frequency of the driver units DU1 - DU3 is too high for the human eye, the eye will perceive a continuous 7.5 pattern.

It should be noted that the input signals S1 - S3 of the driver units DU1 - DU3 may comprise a 12 bit value and can be updated at 240 Hz. The output signal O1 - O3 of the driver units will, however, be a PWM signal with a frequency of 1920 Hz. It should be noted that not sufficient clock cycles are present to fit into a full 12 bit count cycle. Accordingly, the resolution of the PWM signal can drop. This disadvantage can be coped with by splitting the original 12 bit PWM input value into nine upper bits and three lower bits. The upper nine bits correspond to the new PWM values at the multiplied frequency. On the other hand, the remaining three bits correspond to the rest of the signal. These three bits can be used to tweak the PWM value which is to be repeated eight times in the original period of the first frequency. These three bits can be used to perform the above described noise shaping technique. Each value of the three bits can be associated to an action. As an example, if the three bits correspond to "001", the value of the eighth PWM is increased by one. If the bits correspond to "010", the value of the fourth and the eighth PWM value can be increased by one. If the remainder corresponds to "011", the value of the fourth, sixth and eighth PWM can be increased by one. If the three bits correspond to "100", the value of the second, fourth, sixth and eighth PWM can be increased by one. If the remainder corresponds to "101", the value of the second, fourth, sixth, seventh and eighth PWM can be increased by one. If the three bits correspond to "110", the value of the second, third, fourth, sixth, seventh and eighth PWM can be increased by one. If the three bits correspond to "111", the value of the second, third, fourth, fifth, sixth, seventh and eighth PWM is increased by one. As an example, if the input value corresponds to hexadecimal 642, i.e. "0100 0100 0101", this value will be split into "01 10 0100 0" and "0100 0". In other words, the lower three bits correspond to "010", i.e. the fourth and eighth value of the PWM should be increased. Accordingly, the output PWM pattern may correspond to C8, C8, C8, C9, C8, C8, C8, C9 in hexadecimal or in a binary format: "01 10 0100 0", "01 10 0100 0", "01 10 0100 0", "01 10 0100 1", "01 10 0100 0", "01 10 0100 0", 0 1 1 0 0 1 0 0 0", "01 10 0100 1".
It should be noted that the values of the last three bits may also be associated to other actions than the above described.

By means of the modulation pattern unit MPU and the summation of the multiplied input signals S1 - S3, the strings of LEDs can be driven at a much higher frequency, wherein a sinewave can be superimposed on top of the above-mentioned PWM values. For each of the PWM input values at 240 Hz (first frequency), the driver units generate 8 PWM output cycles at the second frequency of for example 1920 Hz. In other words, 8 samples may be used to modulate a pattern of the first frequency, e.g. 240 Hz on top of an average value. As the frequency of the PWM is too high for a human eye to see it, the user will not perceive it. However, this signal can be detected by a sensor.

The control unit CU can control the driver unit DU1 - DU3 such that only one string of LEDs is using a calibration pattern, while the others are operating as usual (without calibration pattern). Additionally, the control unit CU can control the driver unit DU1 - DU3 such that individual strings are in either oversampling mode or in normal mode. The calibration pattern introduced by the modulation pattern unit MPU can be a sinewave or alternatively a programmable pattern. This programmable pattern can for example be downloaded to the driver units and can for example be +5, -5, +5, -5. It should be noted that the modulation pattern does not need to be the same for all of the driver units, i.e. a different pattern may be used for red, green or blue.

Fig. 3 shows a schematic block diagram of a display device according to a third embodiment. The display device comprises a driver unit DU1, a string of LEDl and a sensor unit SU. The driver unit according to the Fig. 3 substantially corresponds to the driver unit according to Fig. 2B with the exception that the block NS is not present. The driver unit DU1 drives the first strings of LEDs LEDl which emit light than can be detected by the sensor unit SU. The sensor unit SU comprises a light detecting sensor S which is coupled to an amplifier A and which in turn is coupled to a Band pass filter BPF. The light emitted by the strings of LEDs LEDl will have light intensities which include a sinewave using eight samples which are superimposed on the PWM signal, which is running at 240 x 8 Hz. In order to filter
the calibration signal from the received light intensities, the Band pass filter BPF is provided.

Fig. 4 shows a graph of a modulation spectrum according to the fourth embodiment. The modulation spectrum of the PWM has a base frequency of 240 Hz. In Fig. 4, apart from the base frequency, a number of odd harmonics at multiples of the base frequency are depicted. Accordingly, in Fig. 4, needles at 240 Hz, 248 Hz, 720 Hz and all subsequent multiples of 240 Hz are depicted. It should be noted that if the ratio of the PWM changes, the needles in the modulation spectrum will remain at their frequency but the amplitudes thereof can change.

If the oversampling of the driver unit is provided by multiplying the input frequencies, the modulation spectrum will in principle have the same form but the frequency needles will be at multiples of 1920 Hz.

Fig. 5 shows a graph of a modulation spectrum according to a fourth embodiment. Here, the modulation spectrum of the oversampled driver unit is depicted.

If the LED matrix of the backlight unit is considered as a whole, some of the strings of LEDs or the LED segments will be in a normal mode while others can be in an upsampled mode which may correspond to the calibration mode. If for example only one LED segment is in the normal mode, i.e. operating at the first frequency (240 Hz) while all the other LED segments are operated in the oversample mode, the sensor unit SU will pick up a compound signal of all LED segments. In Fig. 6, the contribution of the first and second frequency in the modulation spectrum is depicted.

Fig. 6 shows a graph depicting the modulation spectrum according to a fourth embodiment. In this embodiment, a low pass filter LPF is used to filter out a signal coming from the LED segments that need to be monitored. The result of the low pass filtering can be used to determine a contribution of a single LED segment. In addition or alternatively, this can be performed on a sequentially matter such that one LED segment after another can be measured. The result will be an array of measurement values. The sequential measurements can be used to compare the intensity of each of the strings of LEDs or LED segments to each other. Thereafter, the controller can adapt the signals S1 - S3 accordingly. In particular, those LEDs,
strings of LEDs or segments of LEDs which have a low amplitude require more current while the others which have an amplitude which is too high require less current.

Optionally, a geometrical distance compensation needs to be performed in order to compensate for the differences in the distance between the sensor and the LED segments. However, this compensation may include a static multiplication factor. Here, it should be noted that the light intensity drops with the square of the distance between the sensor and the LED segment.

The present invention relates to the idea to calibrate a backlight in a display device or the display panel having an LED in a display device. This calibration should be performed without being perceived by a viewer. Due to the temperature drift, the colour of the LEDs in the backlighting may change over time. Therefore, it is desirable to obtain a uniform backlighting. This can be achieved by the calibration process described above. The calibration methods according to the prior art are disadvantageous as they can lead to artifacts which can be annoying for a viewer.

The principles of the present invention may also be applied to displays using organic light emitting diodes OLED.

The present invention is in particular advantageous for display panels or backlighting with mixed colors or multiple colors.

Typically, the light emitting devices are driven by a pulse width modulation PWM signal in order to achieve for example the right light intensity. According to the invention, the PWM signal is modulated with a modulation pattern. The sensor unit SU detects the light emitted by the light emitting units and can extract the modulation pattern. This information is forwarded to the calibration unit C. The modulation of the PWM signal can be performed sequentially such that the sensor unit SU sequentially detects the modulation pattern for each string of LEDs. By means of the modulation of the pulse width modulation signal, a test pattern is added on top of this signal. Preferably, this test pattern is not visible for the human eye.

Optionally, the sensor unit SU can comprise a band pass filter to detect or to filter out all frequencies not related to the test pattern.
The amount of the modulated signal for each segment is detected by the sensor unit SU and is forwarded to the calibration unit, where it can be stored until all segments have been detected. Then the modulated output of each segment of LEDs is compared to each other by means of the calibration unit C. The control unit CU is informed if the modulated signal of a segment deviates from the modulated signals from the other signals. Then, the control unit CU adapts the control of this particular segment of LEDs to such an extent that the modulated signal of this segment corresponds substantially to the modulated signal of other segments. Moreover, optionally the distance between a segment of LEDs and the sensor unit is taken into account and is compensated.

The above described calibration process can be performed continuously once every ten minutes, once every hour, etc.

Fig. 7 shows a basic representation of a display device according to a fifth embodiment. In Fig. 7 the dots relate to different light emitting devices LED and the x relate to a sensor unit which can be implemented by a flux sensor, a color sensor etc. Preferably, two sensor units SU are provided. Each sensor unit SU should be provided in the middle of a half of the display. The position of the sensor units according to Fig. 7 is a trade-off between the receivable light levels and the required dynamic range. If a sensor is arranged close to the edge of a panel, the sensor unit will receive more light from far way LED as their light is reflected to the side of the backlight unit. On the other hand, the dynamic range requirements of the sensors need to be taken into account. It should be noted that the light received by a sensor is a function of the distance of the light source to the sensor. In particular, the relation is an inverse square law behavior. The sensor in the left part of the screen is used to calibrate the right half of the screen and the sensor arranged in the right part of the screen is used to calibrate the left half of the screen, i.e. the strings of LEDs arranged in the left half of the screen.

The above described sensor unit SU can be arranged either on a layer in front of the strings of LEDs, or on the same plane with the LED devices. In the latter case the sensor(s) will detect the reflected light. Preferably, several sensor units are provided to detect the light emitted by the segments of LEDs. A cost optimal solution will be to mount 2 sensors: One positioned in the left half of the screen to
calibrate the right half of the screen and another sensor positioned in the right half of
the screen to calibrate the left half of the screen. This method of using 2 sensors will
reduce the dynamic range that is required for the sensor design.

It should be noted that the above-mentioned embodiments illustrate
rather than limit the invention, and that those skilled in the art will be able to design
many alternative embodiments without departing from the scope of the appended
claims. In the claims, any reference signs placed between parentheses shall not be
construed as limiting the claim. The word "comprising" does not exclude the presence
of elements or steps other than those listed in a claim. The word "a" or "an" preceding
an element does not exclude the presence of a plurality of such elements. In the device
claim enumerating several means, several of these means can be embodied by one and
the same item of hardware. The mere fact that certain measures are recited in
mutually different dependent claims does not indicate that a combination of these
measures cannot be used to advantage.

Furthermore, any reference signs in the claims shall not be constrained
as limiting the scope of the claims.
CLAIMS:

1. Display device, comprising:
   a display panel (PU) for displaying a video signal;
   a backlight unit (BLU) for backlighting the display panel (PU) and having a plurality of strings of light emitting devices (LED1-LED3) for emitting light;
   and
   at least one sensor unit (SU) for detecting at least the light emitted by the strings of light emitting devices (LED1-LED3) of the backlight unit (BLU);
   wherein the backlight unit (BLU) further comprises a plurality of driver units (DU1-DU3) each for driving a string of light emitting devices (LED1-LED3), a control unit (CU) for controlling each of the plurality of driver units (DU1-DU3), and a calibration unit (C) for receiving the output signal of the sensor unit (SU) and for providing calibration information to the control unit (CU);
   wherein each driver unit (DU1 - DU3) comprises a modulation pattern unit (MPU) for providing a modulation pattern at a multiple of the frequency of the output signal from the control unit (CU) and a mixing unit (MU) for mixing a frequency multiplied control signal from the control unit (CU) with the modulation pattern, wherein the output signal of the mixing unit (MU) is applied to one of the strings of light emitting devices (LED1 - LED3);
   wherein the control unit (CU) is provided to adapt the controlling of the plurality of driver units (DU1 - DU3) based on the calibration information from the calibration unit (CU);
   wherein the sensor unit (SU) is adapted to detect the modulation pattern in the light emitted by the strings of light emitting devices (LED1 - LED3) and to forward the detected modulation pattern to the calibration unit (C).

2. Display device according to claim 1, wherein the sensor unit (SU) comprises a filter (BFP) for the modulation pattern in the light emitted by the strings of light emitting devices (LED1 - LED3).
3. Display device according to claim 1 or 2, wherein each driver unit (DU1 - DU2) comprises a pulse width modulation unit (PWMO) for performing a pulse width modulation based on a summation of the frequency multiplied output signal from the control unit (CU) and the modulation pattern from the modulation pattern unit (MPU).

4. Display device according to claim 1, 2 or 3, wherein the control unit (CU) is adapted to drive the driver units (DU1 - DU3) to perform the calibration for each string of light emitting devices (LED1 - LED3) sequentially,

wherein the calibration unit (C) is adapted to store the output signal of the sensor unit (SU) for each string of LEDs, wherein the calibration unit (C) is adapted to determine whether the light emitted by a string of LEDs deviates from the light emitted by adjacent strings of LEDs,

wherein the control unit (CU) is adapted to adjust the control for the driver unit associated to the string of LEDs deviating from the other strings of LEDs in order to calibrate this string of LEDs.

5. Display device according to any one of the claims 1 to 4, wherein the calibration is performed continuously, once every ten minutes or once every hour.

6. Display device according to anyone of the claims 1 to 5, wherein the sensor unit comprises two sensors, wherein one sensor is arranged in the middle of a left half of the display and the second sensor is arranged in the middle of the right half of the display.

7. Display device, comprising:

   a display panel (PU) for displaying a video signal and having a plurality of strings of light emitting devices for emitting light, and

   at least one sensor unit (SU) for detecting at least the light emitted by the strings of light emitting devices (LED1-LED3);
wherein the display panel (PU) further comprises a plurality of driver units (DU1-DU3) each for driving a string of light emitting devices (LED1-LED3), a control unit (CU) for controlling each of the plurality of driver units (DU1-DU3), and a calibration unit (C) for receiving the output signal of the sensor unit (SU) and for providing calibration information to the control unit (CU);

wherein each driver unit (DU1 - DU3) comprises a modulation pattern unit (MPU) for providing a modulation pattern at a multiple of the frequency of the output signal from the control unit (CU) and a mixing unit (MU) for mixing a frequency multiplied control signal from the control unit (CU) with the modulation pattern, wherein the output signal of the mixing unit (MU) is applied to one of the strings of light emitting devices (LED1 - LED3);

wherein the control unit (CU) is provided to adapt the controlling of the plurality of driver units (DU1 - DU3) based on the calibration information from the calibration unit (C);

wherein the sensor unit (SU) is adapted to detect the modulation pattern in the light emitted by the strings of light emitting devices (LED1 - LED3) and to forward the detected modulation pattern to the calibration unit (C).

A method of controlling a display device comprising a plurality of strings of light emitting devices (LED1 - LED3) for emitting light, comprising the steps of:

detecting at least the light emitted by the strings of light emitting devices (LED1 - LED3),

driving a string of light emitting devices (LED1 - LED3) by a driver unit (DU1 - DU3),

controlling the driving of each string of light emitting devices (LED1 - LED3) by a control unit (CU),

receiving the light emitted by the strings of light emitting devices by a sensor unit (SU),

providing calibration information,

providing a modulation pattern at a multiple of the frequency of the output of the control unit (CU),
mixing a frequency multiplied control signal from the control unit (CU) with the modulation pattern,
applying the output signal of the mixing unit (MU) to at least one of the strings of light emitting devices (LED1 - LED3),

adapting the controlling of the plurality of driver units (DU1 - DU3) based on the calibration information, and

detecting the modulation pattern in the light emitted by the strings of light emitting devices (LED1 - LED3) and forwarding the detected modulation pattern to the calibration unit (C).

9. Method of controlling a display device according to claim 8, wherein two sensor units (SU) are used to calibrate the strings of light emitting devices (LED1-LED3), wherein a first sensor unit is located in a left part of a screen and serves to calibrate the right half of the screen and a second sensor is located in the right part of the screen and is used to calibrate the left half of the screen.
Fig. 1

Fig. 2A

Fig. 2B
Fig. 3

$\frac{1}{T}$

$\frac{3}{T}$

$\frac{5}{T}$

$\frac{7}{T}$

$f_{PWM} = 240\text{Hz}$

Fig. 4

harmonics of 240Hz

Fig. 5

use LPF to get nd of 1920Hz components

Fig. 6
Fig. 7

• = LED
× = SU
**A. CLASSIFICATION SUBJECT MATTER**

INV.  G09G3/34  H05B33/08

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

**B. FIELOS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)

G09G  H05B

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

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

EPO-Internal

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

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**D.** Further documents are listed in the continuation of Box C

See patent family annex

* Special categories of cited documents

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**Date of the actual completion of the international search**

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