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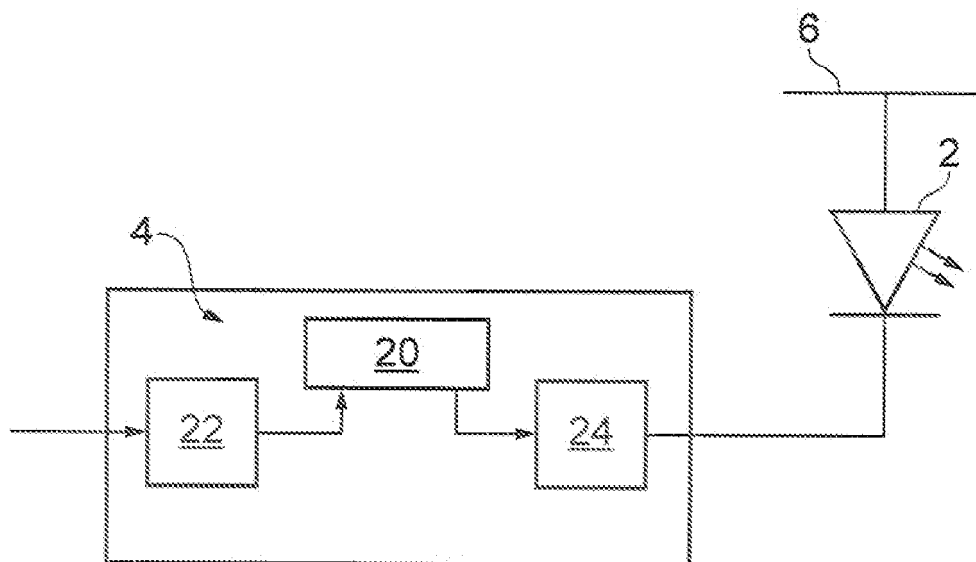
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AL BA RS(71) Applicant: **NXP B.V.****5656 AG Eindhoven (NL)**(72) Inventor: **Schmitz, Hans****Redhill, Surrey RH1 1DL (GB)**(74) Representative: **Burton, Nick****NXP Semiconductors****IP&L Department****Betchworth House****57-65 Station Road****Redhill, Surrey RH1 1DL (GB)**(54) **Apparatus and method for applying a gamma correction**

(57) A light emitting diode (LED) driver (4) for an LED backlighting system in a display. The driver includes an input (22) for receiving a driver signal. A correction unit applies a non-linear correction to the driver signal to pro-

duce a gamma corrected driver signal. The gamma correction compensates for the non-linear perceptual response of the human eye to luminance information. The LED driver also includes an output (24) for outputting the gamma corrected driver signal to one or more LEDs (2).

**FIG. 2**

Description

BACKGROUND OF THE INVENTION

[0001] This invention relates to an apparatus and method for applying a gamma correction. In particular, this invention relates to an apparatus and method for applying a gamma correction to a driver signal in an LED backlighting system for a display.

[0002] It is known to provide LED backlighting for displays such as LCD TVs. Typically, an LED backlighting system may comprise a large number of LEDs (hundreds, or even thousands), since a single LED can not provide enough luminance to backlight the whole display. The LEDs in the system can be arranged towards the sides of the display (side-lit) or in a matrix behind the display (direct-lit).

[0003] In advanced backlight systems, a control system can be provided to compensate for factors such as aging effects, colour drift as an effect of temperature, and uniformity errors (e.g. due to manufacturing variations). Because of these factors, in the absence of some form of compensation system, there may be large variations in luminance output at identical current levels between the LEDs, resulting in a non-uniformly lit backlight. To provide a uniformly backlit display, a controller can be used to reduce or increase the luminance of each individual LED in the system. The controller can control the output luminance of each LED by adjusting a duty cycle of the driver signal applied to the LED. This is preferable to adjusting the peak current applied to the LED, since changes in the peak current can change the output wavelength of the LED.

[0004] Due to the large number of LEDs that are typically employed in an LED backlighting system, and the need to provide individual control to the LEDs to produce the desired (e.g. uniform) output, it is clear that a very large number (several hundred, or even thousands) of PWM control signals become necessary. Moreover, the control signals may need to be updated in real time, according to the output of the display itself. For example, when the backlighting system is performing 2D dimming in order to produce enhanced contrast values, each of the PWM control signal has to be updated for every video frame (60 Hz).

[0005] It is known that the human eye responds to changes in luminance information in a non-linear (in particular, logarithmic) fashion. For example, at relatively high light levels, relatively large changes in actual luminance are required to produce a given change in perceived luminance. On the other hand, at lower light levels, relatively small changes in actual luminance are required to produce a given change in perceived luminance. This non-linearity in the response of the human eye to change in luminance levels can complicate efforts to produce a display that appears to the human eye to be uniformly backlit.

SUMMARY OF THE INVENTION

[0006] Aspects of the invention are set out in the accompanying independent and dependent claims. Combinations of features from the dependent claims may be combined with features of the independent claims as appropriate and not merely as explicitly set out in the claims.

[0007] According to an aspect of the invention, there is provided a light emitting diode (LED) driver for an LED backlighting system in a display. The driver includes an input for receiving a driver signal. The driver also includes a correction unit for applying a non-linear correction to the driver signal to produce a gamma corrected driver signal, wherein the gamma correction compensates for the non-linear perceptual response of the human eye to luminance information. The driver further includes an output for outputting the gamma corrected driver signal to one or more LEDs.

[0008] According to another aspect of the invention, there is provided a method of applying a gamma correction to a driver signal in an LED backlighting system for a display. The method includes receiving the driver signal at an LED driver of the backlighting system. The method also includes the LED driver applying a non-linear correction to the driver signal to produce a gamma corrected driver signal, wherein the gamma correction compensates for the non-linear perceptual response of the human eye to luminance information. The method further includes the LED driver outputting the gamma corrected driver signal to one or more LEDs.

[0009] By correcting the driver signal to compensate for the non-linear perceptual response of the human eye to luminance information, the actual level of backlighting applied to a display can be appropriately set according to an intended perceived level. Moreover, as the correction is performed in an LED driver of the backlighting system, (a stage at which the actual driver signal for driving the LED is determined), output controllers (such as a display driver) operating upstream of the LED driver can work in a linear fashion, without needing to include a gamma corrections in their backlighting calculations. Since gamma corrected backlighting driver signals typically require larger word size (e.g. 16 or 12 bit vs. 8 bit), this in turn reduces the amount of processing power needed upstream of the LED driver. A simpler, cheaper processor may therefore be used to implement features such as the display driver. Additionally, since the driver signals received by the LED driver are non-gamma corrected, the communications overhead to the LED driver is reduced. These reductions can significantly reduce the complexity and cost of a backlighting system, which may comprise a large number of LED drivers and LEDs.

[0010] In one embodiment, the gamma corrected driver signal can comprise a pulse width modulated (PWM) signal. The gamma correction can be applied by adjusting a duty cycle of the pulse width modulated driver signal.

[0011] In one embodiment, the correction applied to

the driver signal can be used to correct for further factors, in addition to compensating for the non-linear perceptual response of the human eye to luminance information. For example, the correction values can correct for non-linear output behaviour in an LED of the LED backlighting system. Such non-linear output behaviour may arise from factors such as aging of the LED, temperature dependent shifts in output intensity, and uniformity errors arising from variations in the manufacture and assembly of the LED. In other examples, the correction values can be operable to correct for non-linear output behaviour in the display screen itself (e.g. non-linear behaviour in an LCD sitting in front of the backlighting system).

[0012] The correction unit can, in one example, comprise memory for storing gamma correction values for applying the non-linear correction to the driver signal. The driver signal itself may act as an address for accessing the appropriate memory location in which a value corresponding to the gamma corrected driver signal is stored. The memory can, for example, comprise a look-up table (LUT).

[0013] According to another aspect of the invention, there is provided an LED backlighting system for a display. The system includes one or more LEDs. The system also includes an LED driver of the kind described above, for driving the one or more LEDs. The system can include further LEDs and LED drivers, with each driver being responsible for driving one or more of the LEDs.

[0014] According to a further aspect of the invention, there is provided apparatus comprising a display driver for driving the output of a display, and an LED backlighting system of the kind described above. The display driver is operable to send the driver signal to the input of the LED driver.

[0015] According to another aspect of the invention, there is provided a display comprising the LED backlighting system of the kind described above.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] Embodiments of the present invention will be described hereinafter, by way of example only, with reference to the accompanying drawings in which like reference signs relate to like elements and in which:

Figure 1 shows an LED backlighting system for a display, in accordance with an embodiment of the invention;

Figure 2 shows an LED driver and an LED, in accordance with an embodiment of the invention; and
Figure 3 shows an LED driver, in accordance with an embodiment of the invention.

DETAILED DESCRIPTION

[0017] Embodiments of the present invention are described in the following with reference to the accompanying drawings.

[0018] A first embodiment of the invention is illustrated schematically in Figure 1. In accordance with this embodiment, there is provided a backlighting system 10, which includes one or more light emitting diode (LED) drivers 4 for driving a plurality of LEDs 2. As illustrated in Figure 1, the LEDs 2 are connected between a supply voltage rail 6 and the LED drivers 4. In this example, the LED drivers 4 are connected by a serial connection 8 to a controller 12. The controller 12 may, for example, comprise a display controller. The display controller may be responsible for configuring the output of the display, as well as for determining the appropriate backlighting levels required for the display on a real time basis. The backlighting levels may themselves depend upon the output of the display at a given moment in time. In an alternative example, the controller 12 may be dedicated to producing driver signals for controlling the LED drivers 4, and for coordinating the relative levels of the LEDs 2 of the backlighting system 10. In such examples, the controller 12 may receive control signals from a separate display driver, indicating the appropriate backlighting levels that are desired at a given moment in time.

[0019] In operation, the controller 12 outputs driver signals via the serial interface 8 for controlling the individual LED drivers 4. The LED drivers 4 respond to the driver signals received at respective inputs of the LED drivers 4 via the serial interface 8 by outputting appropriate driver signals for controlling the LEDs 2 of the backlighting system 10 to produce the desired backlighting conditions.

[0020] Typically, the driver signals provided by the LED drivers 4 to the LEDs 2 comprise pulse width modulated (PWM) signals. As already discussed above, using pulse width modulation to alter the duty cycle of the driver signal applied to the LEDs allows the perceived brightness of the LEDs to be varied without varying the peak applied current, whereby the output spectrum of the LEDs 2 is not adversely affected in terms of peak output wavelength.

[0021] In accordance with an embodiment of the invention, the driver signals that are provided by the LED drivers 4 to the LEDs 2 are gamma corrected. In particular, the driver signals compensate for the non-linear perceptual response of the human eye to luminance information. As discussed above, the human eye does not respond to luminance information in a linear manner. Instead, the human eye has a perceptual response which is approximately logarithmic in terms of perceived brightness. Thus, at relatively low intensities, relatively small changes in actual brightness are required to achieve a desired perceived change by the human eye. However, at high intensities, relatively large changes in actual intensity are required to produce a desired perceived change in intensity. The gamma corrected driver signals outputted by the LED drivers 4 correct for this perceptual response, whereby the backlighting levels perceived by the human eye can at least approximate the desired backlighting levels determined by, for example, the controller 12 and/or a display controller of the display.

[0022] In accordance with an embodiment of the invention, a gamma correction to compensate for the non-linear perceptual response of the human eye is performed by the display drivers 4, such that these gamma corrections do not need to be performed upstream of the display drivers 4. The allocation of the task of applying the gamma correction to the LED drivers 4 has a number of benefits.

[0023] Firstly, it is noted that gamma corrected signals, which need to cover a wide range of luminance values (owing to the logarithmic correction that is to be applied), typically require a larger word length than non-gamma corrected driver signals. By way of example, whereas a non-gamma corrected driver signal may require an 8 bit word, a gamma corrected signal may require a 12 or even a 16 bit word. The fact that the conversion of the non-gamma corrected driver signal to a gamma-corrected driver signal takes place at the LED drivers 4 means that the controller 12 shown in Figure 1 does not need to use, for example, 12 or 16 bit calculations in determining the appropriate control signals to pass to the LED drivers 4. This means that a simpler, cheaper microprocessor can be used to implement the controller 12. Additionally, the signals provided by the controller 12 to the LED drivers 4 via the serial interface 8 are non-gamma corrected and therefore the serial interface 8 needs only to support the smaller word length. Thus, the communications overhead between the controller 12 and the LED drivers 4 is substantially reduced and, for example, a simpler, cheaper serial interface 8 can be employed. This particular advantage can be particularly significant in a backlighting system comprising a large number (for example, thousands) of LEDs driven by a large number of LED drivers 4.

[0024] Figure 2 schematically illustrates an LED driver 4 of the kind shown in Figure 1 in more detail. As shown in Figure 2, the LED driver 4 includes an input 22 (for example a serial input) for receiving a driver signal. Typically, this driver signal may be received by a serial interface 8 from some form of controller 12 as already discussed above in relation to Figure 1. Also as discussed above, the LED driver 4 is configured to apply a gamma correction to the driver signal received via the input 22.

[0025] The driver signal received at the input 22 typically has a given word length (for example, 8 bit), and to apply the gamma correction, the LED driver 4 can, in this example, use the received word to reference memory 20 and retrieve a gamma corrected driver signal having a different (typically larger) word length. For example, the driver signal word received at the input 22 may itself form an address for accessing the memory 20, where the accessed memory location stores a desired gamma corrected driver signal word. In some examples, the memory 20 may be implemented as a look-up table (LUT). As described below in relation to Figure 3, the gamma corrected driver signal word can subsequently be used to produce a driver signal (e.g. a 1 bit PWM signal) to output to the LED 2 via an output 24 of the LED driver 4. The outputted PWM driver signal has an appropriate duty cy-

cle to produce a desired perceived backlighting level for the LED 2.

[0026] Figure 3 illustrates in further detail an example of an LED driver 4 of the kind described above in relation to Figures 1 and 2.

[0027] As shown in Figure 3, the LED driver 4 includes a serial input 22 for receiving driver signals from a controller 12 of the kind shown in Figure 1. The driver signals are indicative of the backlighting levels that are desired from the LED or LEDs to which the LED driver 4 is connected. As described herein, the LED driver 4 processes the received driver signal by applying a gamma correction and then producing an appropriate driver signal to output to the LEDs themselves for producing the desired perceived backlighting levels.

[0028] The driver signal received by the input 22 is applied to the memory 20 via a connection 32. The memory 20 can take the form of some kind of random access memory (RAM). As described above, the memory 20 can in some examples, take the form of a look-up table. As illustrated by the graph 30 shown in Figure 3, the LED driver 4 applies a non-linear gamma correction to compensate for the non-linear perceptual response of the human eye. The memory 20 can respond to the received driver signal by outputting a gamma corrected driver signal word via connection 36. Typically, the connection 36 can accommodate a longer word length than the connection 32, since the word size of the gamma corrected driver signal is typically larger than the word size of the non-gamma corrected driver signal. The connection 36 delivers the gamma corrected driver signal word to an output stage 24 of the LED driver 4.

[0029] In one embodiment, the contents of the memory 20 can be pre-loaded with correction values for applying the gamma correction to the driver signal. The pre-loading can, in some examples, take place during manufacture. In other examples, the pre-loading can occur at start-up (e.g. when the display is switched on or awakened from a sleep mode). In the example in Figure 3, it is shown that a pre-loading connection 34 can be provided between the input 22 and the memory 20, for performing the pre-loading action. The pre-loading connection can accommodate the longer word length of the gamma corrected driver signal. In operation, the gamma correction values are received at the input 22 via the serial interface 8, and are passed to the memory 20 via the pre-loading connection 34. In other examples, the pre-loading connection 34 can be omitted, and the correction values can be pre-loaded into the memory 20 via the connection 32. However, this would either require that some form of protocol is provided to handle the uploading, since the connection 32 is typically not configured to accommodate word lengths longer than those of the non-gamma corrected driver signals.

[0030] In this example, the output 24 of the LED driver 4 can take the form of a pulse width modulated (PWM driver) driver. The PWM driver of the output 24 converts the gamma corrected driver signal word into a single bit

PWM output for direct application to the LED or LEDs for which the LED driver 4 is responsible. It is noted that although a connection 36 able to accommodate the longer gamma corrected driver signal word length may still be required, this connection is localised to the LED driver 4, and therefore does not significantly impact upon the communications overhead within the backlighting system 10.

[0031] Thus far, it is been described that the gamma correction applied by the LED drivers 4 compensates for the non-linear perceptual response of the human eye to luminance information. However, the gamma correction may also compensate for other factors. For example, the correction may also compensate for known non-linear output behaviour in the LEDs 2 of the backlighting system 10. These non-linearities may, for example, arise from manufacturing variations. Additionally, the gamma correction may also compensate for factors associated with features of the display screen other than the backlighting system. Such features may, for example, correspond to the portions of the display screen that actually produce the display output, such as the LCD which sits in front of the backlighting system.

[0032] Accordingly, there has been described a light emitting diode (LED) driver for an LED backlighting system in a display. The driver includes an input for receiving a driver signal. A correction unit applies a non-linear correction to the driver signal to produce a gamma corrected driver signal. The gamma correction compensates for the non-linear perceptual response of the human eye to luminance information. The LED driver also includes an output for outputting the gamma corrected driver signal.

[0033] Although particular embodiments of the invention have been described, it will be appreciated that many modifications/additions and/or substitutions may be made within the scope of the claimed invention.

Claims

1. A light emitting diode (LED) driver for an LED backlighting system in a display, the driver comprising:

an input for receiving a driver signal;
a correction unit for applying a non-linear correction to the driver signal to produce a gamma corrected driver signal, wherein the gamma correction compensates for the non-linear perceptual response of the human eye to luminance information; and
an output for outputting the gamma corrected driver signal to one or more LEDs.

2. The LED driver of claim 1, wherein the gamma corrected driver signal comprises a pulse width modulated (PWM) signal.

3. The LED driver of claim 2, wherein the gamma cor-

rection adjusts a duty cycle of the pulse width modulated driver signal.

4. The LED driver of any preceding claim, wherein the gamma correction further corrects for non-linear output behaviour in the display.

5. The LED driver of any preceding claim, wherein the gamma correction further corrects for non-linear output behaviour in one or more LEDs of the LED backlighting system.

6. The LED driver of any preceding claim, wherein correction unit comprises memory for storing gamma correction values for applying the non-linear correction to the driver signal.

7. The LED driver of claim 6, wherein the memory comprises a look-up table (LUT).

8. An LED backlighting system for a display, comprising:

one or more LEDs; and
an LED driver according to claim 7, for driving the one or more LEDs.

9. Apparatus comprising a display driver for driving the output of a display, and the LED backlighting system of claim 8, wherein the display driver is operable to send the driver signal to the input of the LED driver.

10. A display comprising the apparatus of claim 9.

11. A method of applying a gamma correction to a driver signal in an LED backlighting system for a display, the method comprising:

receiving the driver signal at an LED driver of the backlighting system;
the LED driver applying a non-linear correction to the driver signal to produce a gamma corrected driver signal, wherein the gamma correction compensates for the non-linear perceptual response of the human eye to luminance information; and
the LED driver outputting the gamma corrected driver signal to one or more LEDs.

12. The method of claim 11, wherein the gamma corrected driver signal comprises a pulse width modulated (PWM) signal.

13. The method of claim 12, wherein applying the non-linear correction to the driver signal adjusts a duty cycle of the pulse width modulated driver signal.

14. The method of any of claims 11 to 13, wherein ap-

plying a non-linear correction to the driver signal further comprises correcting for non-linear output behaviour in an LED of the LED backlighting system.

15. The method of any of claims 11 to 14, wherein applying the non-linear correction to the driver signal comprises accessing a memory holding gamma correction values.

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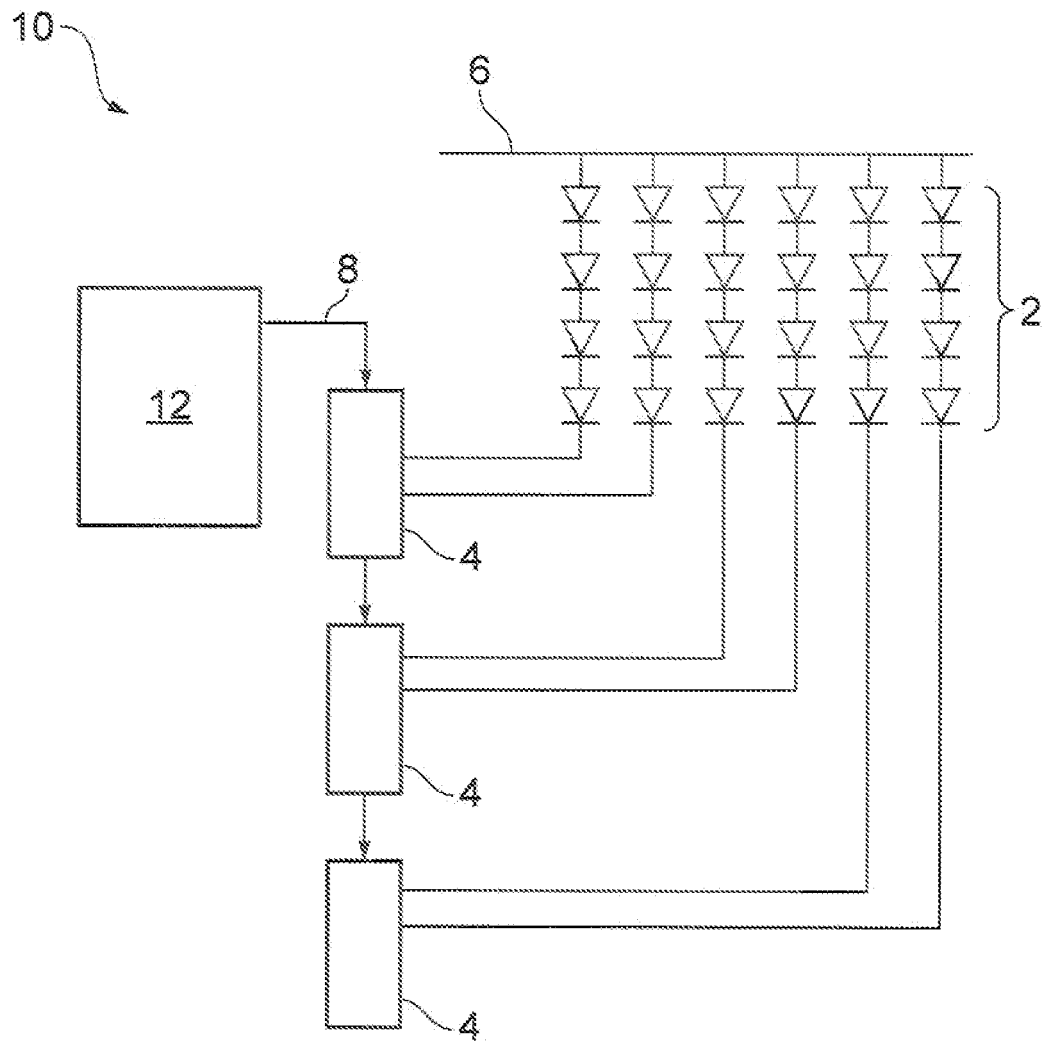


FIG. 1

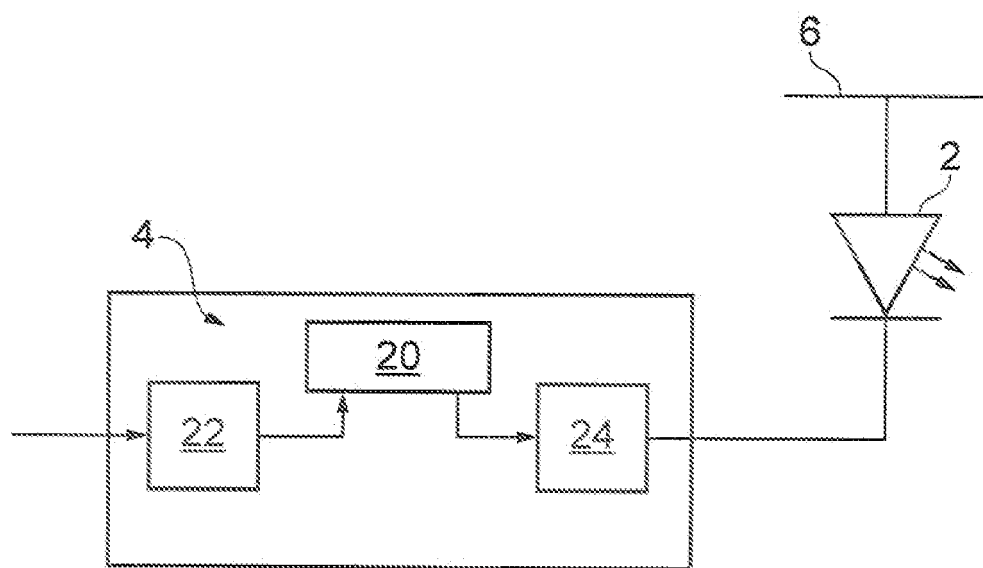


FIG. 2

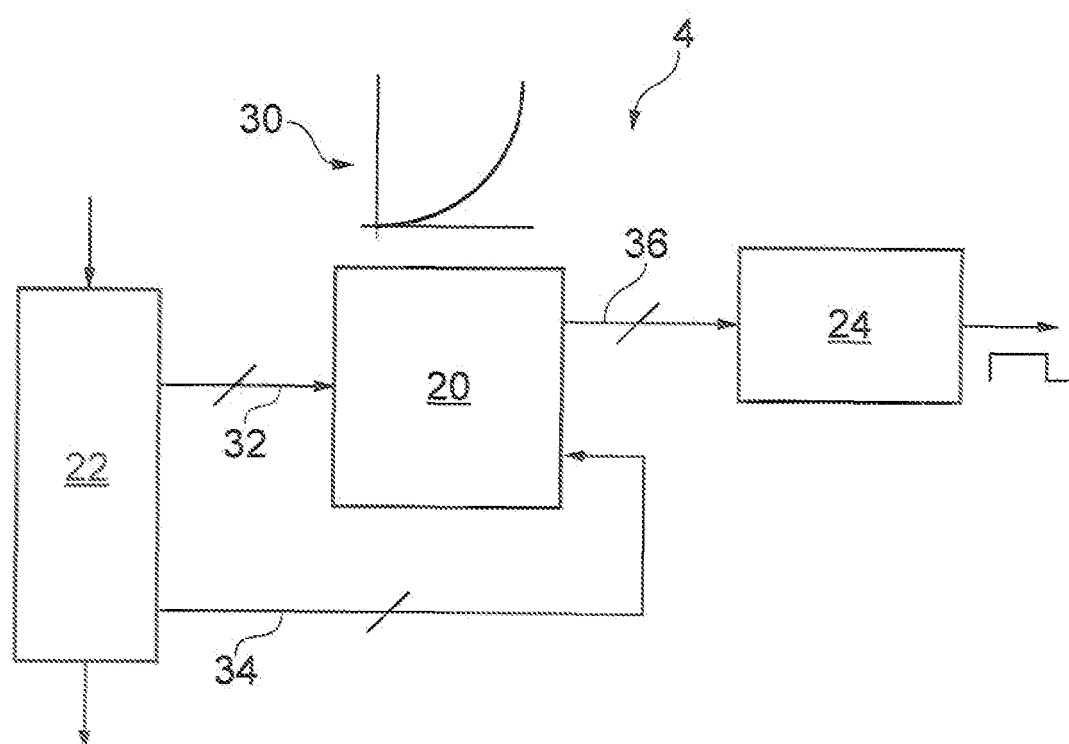


FIG. 3



EUROPEAN SEARCH REPORT

Application Number
EP 09 17 8461

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 2009/189543 A1 (YEO DONG-MIN [KR] ET AL) 30 July 2009 (2009-07-30) * paragraph [0049] - paragraph [0121]; figures 1-9 *	1-3,5-15	INV. G09G3/34
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			TECHNICAL FIELDS SEARCHED (IPC)
			G09G
The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 10 May 2010	Examiner Harke, Michael
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

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**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

EP 09 17 8461

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
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10-05-2010

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