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(54) **LCD display with overdriving to improve discharging time**

(57) An Liquid Crystal Display (LCD) device with a display panel (DP) based on LC material. A driving circuit (C) is arranged to generate and apply a driving voltage (V) to drive the pixels (P) of the panel (DP) in response to the input data. The driving circuit (C) applies an overdriving voltage (V) during discharging of the LC material which is lower than the reference voltage level (Vcom) required to switch off the pixels, and which is further lower than prescribed by the input data. Hereby, the response time of the LC material is improved, and motion blur is thus reduced. In preferred embodiments, the LCD panel and the driving circuit (C) are arranged for a reference voltage level (Vcom) equal to a ground voltage level (GND), and wherein the driving circuit (C) is arranged to apply an overdriving voltage (V) during discharging which is negative compared to the ground voltage level (GND), such as the driving voltage (V) ranging from (-Vs/2) to (+Vs/2) and with (Vcom) centered at 0 V, i.e. based on a symmetrical supply voltage. Especially, the driving voltage (V) may be toggled between (-Vs/2) and (+Vs/2), possibly with an instantaneous shorting of the driving circuit (C) output to ground voltage level (GND) during ramp up and ramp down.

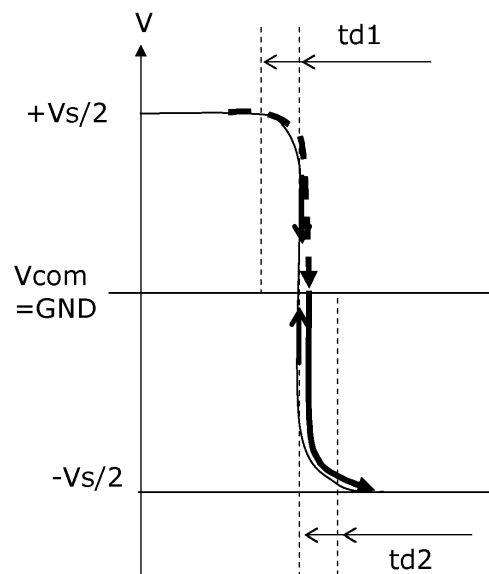


FIG. 3

Description

FIELD OF THE INVENTION

[0001] The present invention relates to the field of display devices. More specifically, the invention relates to Liquid Crystal Display (LCD) displays and methods driving an LCD display which allows an improvement in discharging time, thus reducing tailing and blurring effects when displaying fast moving objects.

BACKGROUND OF THE INVENTION

[0002] Cathode Ray Tube (CRT) based displays and Plasma Display Panel (PDP) type of displays are pulse type displays. Being a hold type display, LCDs have some limitations because of using "slow" response Liquid Crystal (LC) material and a finite backlight holding time. The effect of those limitations, visible to the viewer, is so called tailing or blurring often very visible in light - dark transitions on the screen. The root cause of the motion blur phenomena is a relative low response time.

[0003] Because of the slow response LCD has poor performance in moving pictures as compared to CRT or PDP impulsive devices. In recent years there have been many trials and improvements, like Over-Drive Condition (ODC), cell gap, and LC material switching, to improve response time. As for ODC (Over-Drive Condition) function, rising time may be improved by the use of mere impulsive inputs, however, this will not be the case for the fall time. However, current LCD displays still suffer from a slow fall time.

[0004] US 2010/0231492 A1 discloses an TFT based LCD device where LC response time is improved by reducing charge/discharge time of the TFT transistors in an output portion for providing a gate voltage. Dual gate transistors are used to output the gate voltage, thus reducing charge/discharge time of the output portion. However, US 2010/0231492 A1 does not address the problem of the inherent slow discharge of the LC material.

SUMMARY OF THE INVENTION

[0005] It would be advantageous to provide an LCD and a method for solving the problem of slow discharging of the LC material, so as to provide an LCD display with faster response time and thus improved image quality, especially improved quality of moving images with reduced motion blur.

[0006] In a first aspect, the invention provides a display device arranged to receive input data and to display an image accordingly, the display device comprising:

a Liquid Crystal Display panel comprising a matrix of pixels based on a liquid crystal material, wherein the Liquid Crystal Display panel comprises a driving voltage input at which a reference voltage level corresponds to a voltage where pixels are switched off,

and a driving circuit arranged to apply a driving voltage to the driving voltage input so as to driving the pixels in response to the input data, wherein the driving circuit is arranged to apply an overdriving voltage during discharging which is lower than the reference voltage level and which is lower than prescribed by the input data.

[0007] Such LCD display has a fast response time, since an overdriving voltage is provided to speed up the LC material discharging period, and thus allowing a display device with improved image quality with less motion blur.

[0008] In preferred embodiments, the Liquid Crystal Display panel and the driving circuit are arranged for a reference voltage level which is substantially equal to a ground voltage level, and wherein the driving circuit is arranged to apply an overdriving voltage during discharging which is negative compared to the ground voltage level. By setting the reference voltage level to a ground voltage level, especially using a supply voltage which is symmetrical around the ground voltage level, a more effective overdrive function during discharge can be obtained. Especially, the driving circuit may be arranged to toggle between a positive driving voltage and a negative driving voltage compared to the ground voltage level. E.g. a supply voltage for supplying the driving circuit may be a -9 V/+9 V voltage supply with reference voltage VCOM = 0 V (ground level), compared to a typical supply voltage with 0 V (ground level) and +15-18 V according to prior art with VCOM = +8-9 V.

[0009] To further reduce the discharging time, and thus improve the response time of the display device, the driving circuit may be arranged to instantaneously switch the driving voltage to the ground voltage level, either during a falling driving voltage slope or during a rising driving voltage slope, so as to provide a fast charging period. Preferably, to obtain an optimal effect from this, the driving circuit may be arranged to initiate charging or discharging prior to said switching the driving voltage to the ground voltage level. Especially, the addressing should be earlier than according to prior art, i.e. data reading and on-voltage for an image frame should be performed earlier than in prior art frame timing. Preferably, image signal processing of previous and present image frame should be performed prior to writing to the LC material which is synchronized with a data enable signal of the driving circuit.

[0010] To provide optimal response time, the driving circuit may be arranged to apply an overdriving voltage during charging which is higher than a voltage prescribed by the input data. Thus, with a combination of overdriving applied during charging as well as discharging, an optimal fast driving of the LC material can be obtained.

[0011] In some embodiment, the pixels of the Liquid Crystal Display panel are arranged for being driven according to a color sequential scheme. However, it is to be understood that the invention is also applicable to oth-

er color schemes, e.g. LCD display panels using RGB subpixels.

[0012] The display device may be arranged to receive input data comprising three dimensional (3D) image information and to display an image with 3D attributes accordingly. Especially, said 3D image attributes may be provided by the display being arranged to display temporally separate images intended for viewing by respective left eye and right eye of a viewer. This type of 3D imaging using shutter glass technology requires displays which are very fast in order to reduce reduced 3D image effect due to left-right image cross-talk, and thus the LCD display device according to the invention is suited for 3D applications.

[0013] In preferred implementations, the Liquid Crystal Display panel is implemented as a Thin Film Transistor panel, however other technologies may be used.

[0014] The display device may be a TV set, a computer monitor, or any handheld device, e.g. a mobile device with a display functionality, such as a tablet computer or a mobile phone.

[0015] In a second aspect, the invention provides a method for driving a Liquid Crystal Display panel comprising a matrix of pixels based on a liquid crystal material, the method comprising receiving input data, and applying an overdriving voltage to the Liquid Crystal Display panel during discharging which is lower than the reference voltage level and which is lower than prescribed by the input data. The reference voltage level being the voltage level required to switch off the pixels of the display panel.

[0016] It is appreciated that the same advantages and embodiments of the first aspect apply as well for the second aspect. In general the first and second aspects may be combined and coupled in any way possible within the scope of the invention. These and other aspects, features and/or advantages of the invention will be apparent from and elucidated with reference to the embodiments described hereinafter.

BRIEF DESCRIPTION OF THE DRAWINGS

[0017] Embodiments of the invention will be described, by way of example only, with reference to the drawings, in which

Fig. 1 shows a block diagram of an embodiment of the invention,

Fig. 2 illustrates prior art LCD display discharging,

Fig. 3 illustrates an example of LCD display discharging according to the invention,

Fig. 4 illustrates discharging according to one embodiment,

Fig. 5 illustrates discharging timing for prior art and for an embodiment of the invention, and

Fig. 6 illustrates an embodiment of a method for driving an LCD panel according to the invention.

DESCRIPTION OF EMBODIMENTS

[0018] FIG. 1 illustrates a simple block diagram of an LCD display embodiment of the present invention. An LCD display panel DP has a matrix of pixels P, e.g. a 1080 by 1920 pixel matrix. A driving circuit C receives an input data signal I and generates a driving voltage V according to a driving scheme. The driving voltage is applied to a driving voltage input of the LCD display panel DP so as to drive the pixels P accordingly, i.e. controlling charging and discharging of the LCD pixels P. The driving voltage V is generated taking into account the reference voltage level required at the driving voltage input of the LCD panel to switch off the pixels. According to an embodiment of the invention, the driving circuit C generates the driving voltage V according to an overdriving scheme both for optimal controlling of LC material during charging, but also for optimal controlling of the LC material during discharging, so as to reduce response time of the LC material and thereby provide a display device with a fast response time. To control the LC material during discharging, the driving circuit C generates and applies a driving voltage V which is below a reference voltage level for the LCD display panel DP, and which is further below a voltage level prescribed by the input data 1. i.e. the driving voltage V applied to the display panel DP is below the expected voltage to obtain the luminance level prescribed in the input data 1. This is done in order to speed up the rather slow process of discharging of the LC material. As mentioned, preferably an overdriving scheme is applied also in the charging process.

[0019] The LCD display device according to the invention is suited for high quality moving image reproduction with reduced motion blur. Especially the fast response time may be utilized to provide satisfying image quality also in case of Field Sequential Color (FSC), and for reproduction of time sequential 3D images, where the fast response time will help to reduce left-right cross-talk and thus a better 3D image reproduction.

[0020] FIG. 2 illustrates a graph showing discharging timing in a prior art LCD display. Driving voltage V is shown versus time, and as seen the driving voltage varies within the voltage range 0 V (GND, i.e. ground voltage level) to a positive supply voltage Vs, such as Vs = 16 V or 18 V. The reference voltage level Vcom is positioned at half of the supply voltage, i.e. at Vs/2. The dashed curve illustrates the discharging response of the LC material. The total discharging time is thus td1+td2. It is seen that td2, i.e. the time required for the LC material to reach a charging level below the reference voltage level Vcom, is responsible for the longest response delay.

[0021] FIG. 3 illustrates an example of discharging timing according to the invention on a graph similar to that of FIG. 2. As seen, the reference voltage level Vcom has been moved to 0 V, i.e. ground voltage level GND, and a symmetrical voltage supply is used such that the driving voltage V can be varied between a value of -Vs/2, e.g. a value of -8 V, to a value of +Vs/2, e.g. a value of +8 V.

Thus, altogether the same total voltage range V_s is available as in prior art, but the reference voltage level V_{com} has been moved to the ground voltage level GND. The resulting discharging response delay $td1$ of the LC material at the onset of discharging is seen to be similar to that of FIG. 2. However, below V_{com} , the response delay $td2$ is now similar in size to $td1$, i.e. ramp-down time is now reduced to a time similar to ramp-up time for the LC material. In the prior art, $td2$ is significantly larger than $td1$. Altogether a significant reduction in the total response time $td1+td2$ is obtained compared to the prior art as seen in FIG. 2.

[0022] FIG. 4 shows a graph indicating driving voltage V which is toggled between $+V_s/2$ and $-V_s/2$, and again with the reference voltage level V_{com} set equal to the ground level GND, i.e. 0 V. However, to further actively influence the LC material behavior in order to speed up discharging periods, it is seen inside the dashed circles, that the driving voltage V transitions in both up and down directions are modified by instantaneous shorting the driving circuit output to the ground level GND, and thus forcing the driving voltage V to 0 V. Hereby, an extra fast discharge period is realized, and this instantaneous shorting can easily be realized with known transistor couplings in the driving circuit and provide a very fast switching to the ground level GND

[0023] FIG. 5 shows graphs indicating timing involved in preferred embodiments implementing the instantaneous grounding of the driving voltage explained in connection with FIG. 4. The timing of the "on" voltage signal V_{on} , data read D_r signal are shown together with timing of two subsequent frames $f1$, $f2$. The data charge level D_{ch} is finally indicated. The upper set of curves indicate prior art behavior, while the lower set of curves indicate a preferred embodiment. As seen by comparing with the vertical dashed line, timing of data read D_r and V_{on} are slightly earlier to short the driving voltage to the ground voltage level for faster discharge. The result of the two data charge curves D_{ch} clearly indicates that both ramp up time and ramp down time are steeper than in the prior art, thus indicating an improved response time of the LC material.

[0024] FIG. 6 indicates an example of steps included in an embodiment of a method for driving an LCD display device according to the invention. The first step includes reading input image data RD. Then, a driving voltage is generated and applied to the LCD display panel OD_D, where the driving voltage is generated according to an overdriving scheme with respect to overdriving the LC material during charging as well as during discharging, i.e. where the driving voltage is generated with a more exaggerated voltage swings than prescribed by the input image data. Hereby, the LC material is manipulated to a faster response time, thus improving temporal response of the LCD display device and thereby improving perceived image quality, especially reduced motion blur.

[0025] To sum up, the invention provides an LCD device with a display panel DP based on LC material. A

driving circuit C is arranged to generate and apply a driving voltage V to drive the pixels P of the panel DP in response to the input data. The driving circuit C applies an overdriving voltage V during discharging of the LC material which is lower than the reference voltage level V_{com} required to switch off the pixels, and which is further lower than prescribed by the input data. Hereby, the response time of the LC material is improved, and motion blur is thus reduced. In preferred embodiments, the LCD panel and the driving circuit C are arranged for a reference voltage level V_{com} equal to a ground voltage level GND, and wherein the driving circuit C is arranged to apply an overdriving voltage V during discharging which is negative compared to the ground voltage level GND, such as the driving voltage V ranging from $-V_s/2$ to $+V_s/2$ and with V_{com} centered at 0 V, i.e. based on a symmetrical supply voltage. Especially, the driving voltage V may be toggled between $-V_s/2$ and $+V_s/2$, possibly with an instantaneous shorting of the driving circuit C output to ground voltage level GND during ramp up and ramp down.

[0026] While the invention has been illustrated and described in detail in the drawings and foregoing description, such illustration and description are to be considered illustrative or exemplary and not restrictive; the invention is not limited to the disclosed embodiments.

[0027] Other variations to the disclosed embodiments can be understood and effected by those skilled in the art in practicing the claimed invention, from a study of the drawings, the disclosure, and the appended claims. In the claims, the word "comprising" does not exclude other elements or steps, and the indefinite article "a" or "an" does not exclude a plurality. A single processor or other unit may fulfill the functions of several items recited in the claims. 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. A computer program may be stored/distributed on a suitable medium, such as an optical storage medium or a solid-state medium supplied together with or as part of other hardware, but may also be distributed in other forms, such as via the Internet or other wired or wireless telecommunication systems. Any reference signs in the claims should not be construed as limiting the scope.

Claims

1. A display device arranged to receive input data (I) and to display an image accordingly, the display device comprising:

a Liquid Crystal Display panel (DP) comprising a matrix of pixels (P) based on a liquid crystal material, wherein the Liquid Crystal Display panel comprises a driving voltage input at which a reference voltage level (V_{com}) corresponds to

- a voltage where pixels (P) are switched off, and a driving circuit (C) arranged to apply a driving voltage (V) to the driving voltage input so as to drive the pixels (P) in response to the input data (I), wherein the driving circuit (C) is arranged to apply an overdriving voltage (V) during discharging which is lower than the reference voltage level (Vcom) and which is lower than prescribed by the input data (I).
2. Display device according to claim 1, wherein the Liquid Crystal Display panel (DP) and the driving circuit (C) are arranged for a reference voltage level (Vcom) which is substantially equal to a ground voltage level (GND), and wherein the driving circuit (C) is arranged to apply an overdriving voltage ($-V_s/2$) during discharging which is negative compared to the ground voltage level (GND).
 3. Display device according to claim 1, wherein the driving circuit (C) is supplied by a supply voltage ($-V_s/2$, $V_s/2$) which is substantially symmetrical around the ground voltage level (GND).
 4. Display device according to claim 2, wherein the driving circuit (C) is arranged to toggle between a positive driving voltage ($+V_s/2$) and a negative driving voltage ($-V_s/2$) compared to the ground voltage level (GND).
 5. Display device according to claim 2, wherein the driving circuit (C) is arranged to instantaneously switch the driving voltage (V) to the ground voltage level (GND) during a falling driving voltage slope.
 6. Display device according to claim 5, wherein the driving circuit (C) is arranged to instantaneously switch the driving voltage (V) to the ground voltage level (GND) during a rising driving voltage slope.
 7. Display device according to claim 5, wherein the driving circuit (C) is arranged to initiate charging or discharging prior to said switching the driving voltage (V) to the ground voltage level (GND).
 8. Display device according to claim 1, wherein the driving circuit (C) is arranged to apply an overdriving voltage (V) during charging which is higher than a voltage prescribed by the input data (V).
 9. Display device according to claim 1, wherein the pixels (P) of the Liquid Crystal Display panel (DP) are arranged for being driven according to a color sequential scheme.
 10. Display device according to claim 1, being arranged to receive input data (I) comprising three dimensional image information and to display an image with three dimensional image attributes accordingly.
 11. Display device according to claim 10, wherein said three dimensional image attributes are provided by the display being arranged to display temporally separate images intended for viewing by respective left eye and right eye of a viewer.
 12. Display device according to claim 1, wherein the Liquid Crystal Display panel (DP) is implemented as a Thin Film Transistor panel.
 13. Display device according to claim 1, being one of: a TV set, a computer monitor, and a hand-held device.
 14. Method for driving a Liquid Crystal Display panel comprising a matrix of pixels based on a liquid crystal material, the method comprising:
 - receiving input data, and
 - applying an overdriving voltage to the Liquid Crystal Display panel during discharging which is lower than the reference voltage level required to turn off the pixels, and which is lower than prescribed by the input data.

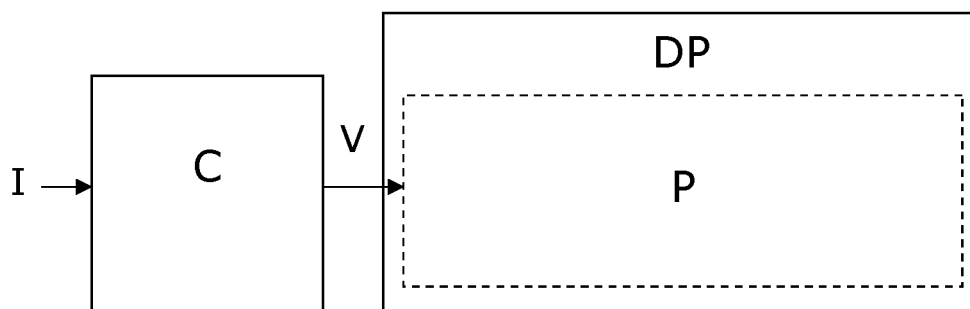


FIG. 1

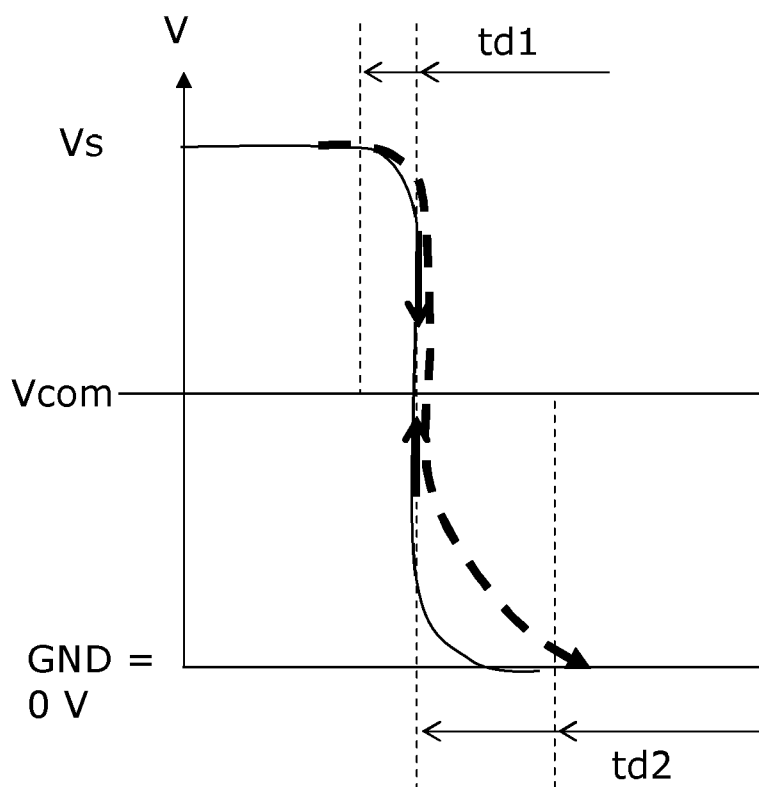


FIG. 2
PRIOR ART

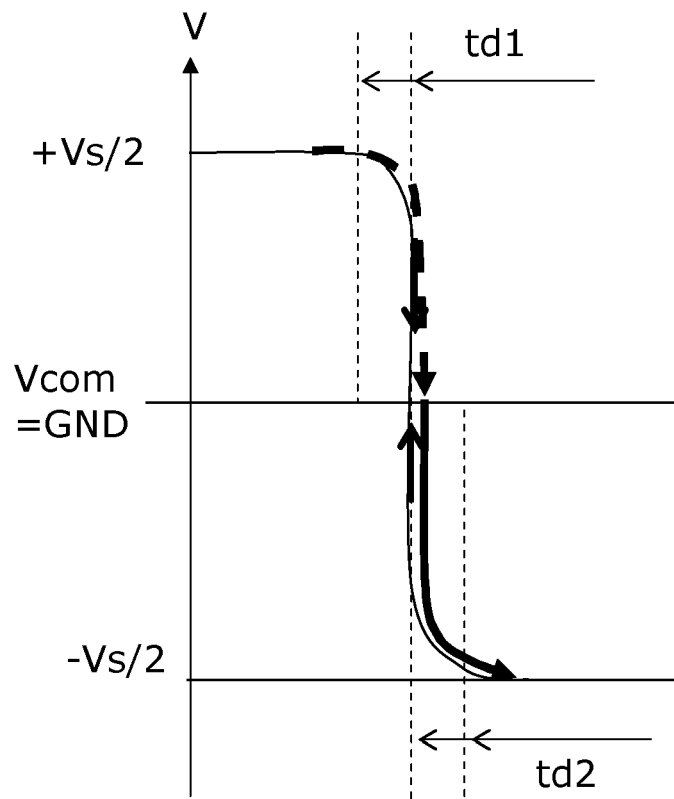


FIG. 3

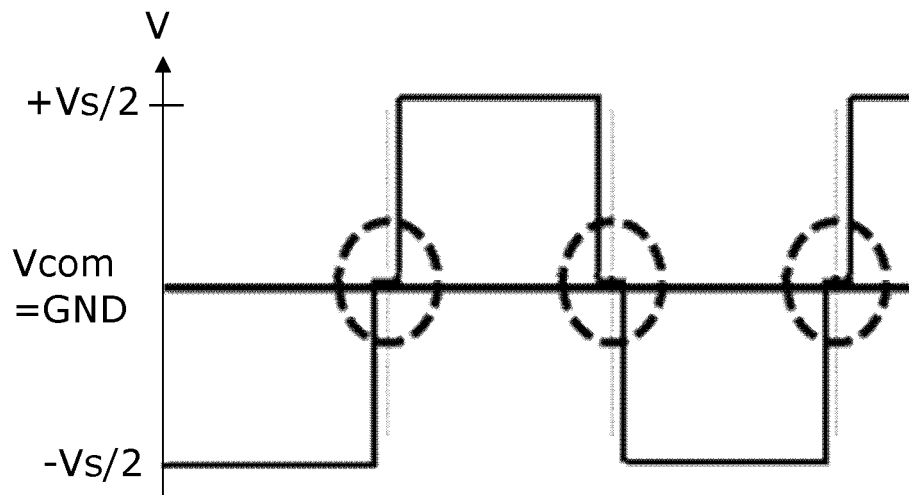


FIG. 4

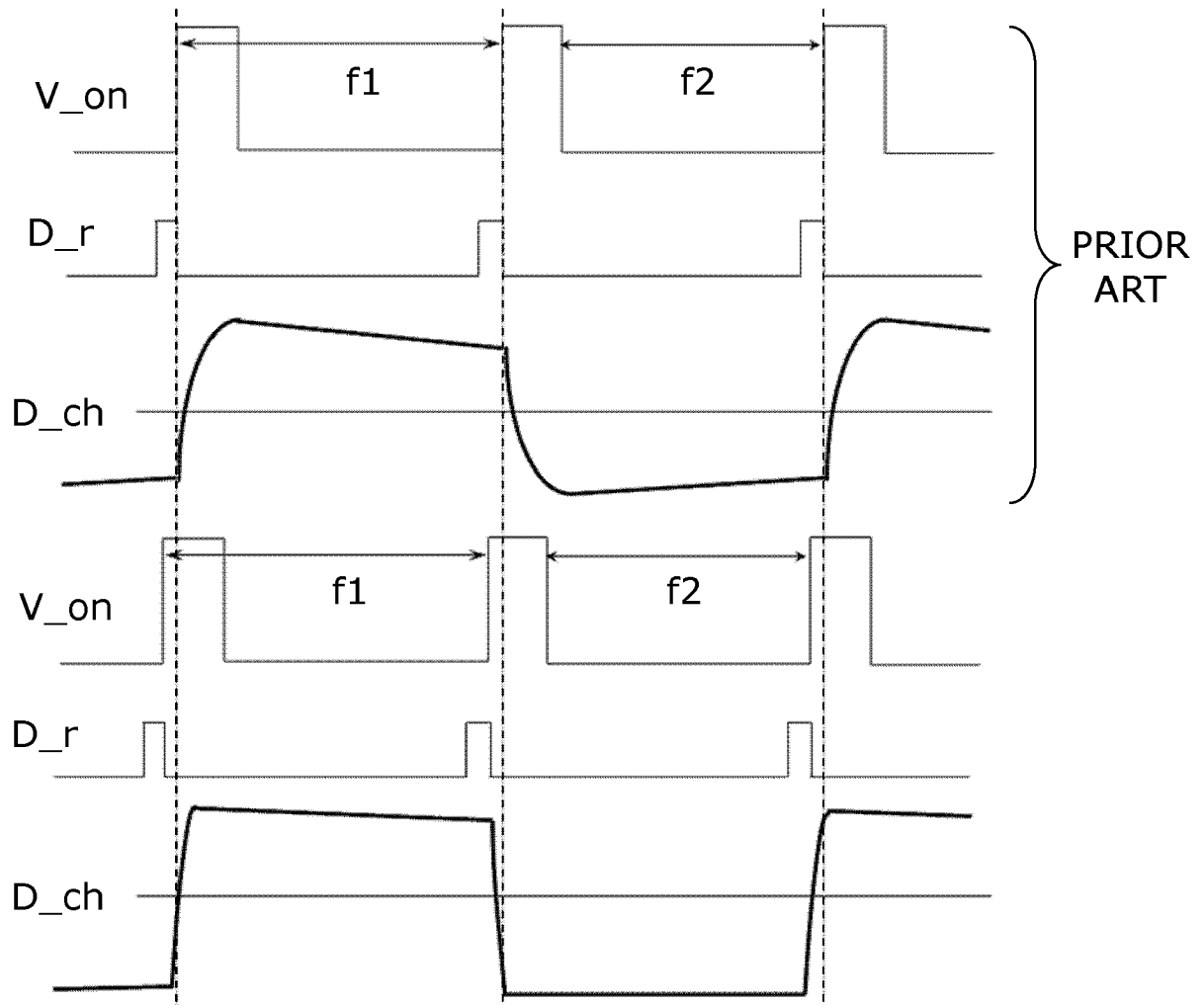


FIG. 5

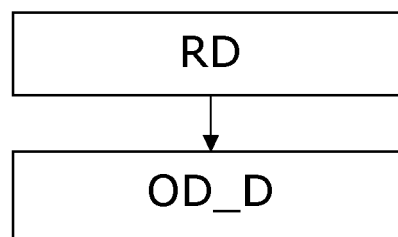


FIG. 6



EUROPEAN SEARCH REPORT

Application Number
EP 11 17 4550

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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Place of search Munich		Date of completion of the search 19 October 2011	Examiner Taron, Laurent
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
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This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
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