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(54) **DISPLAY DEVICE**

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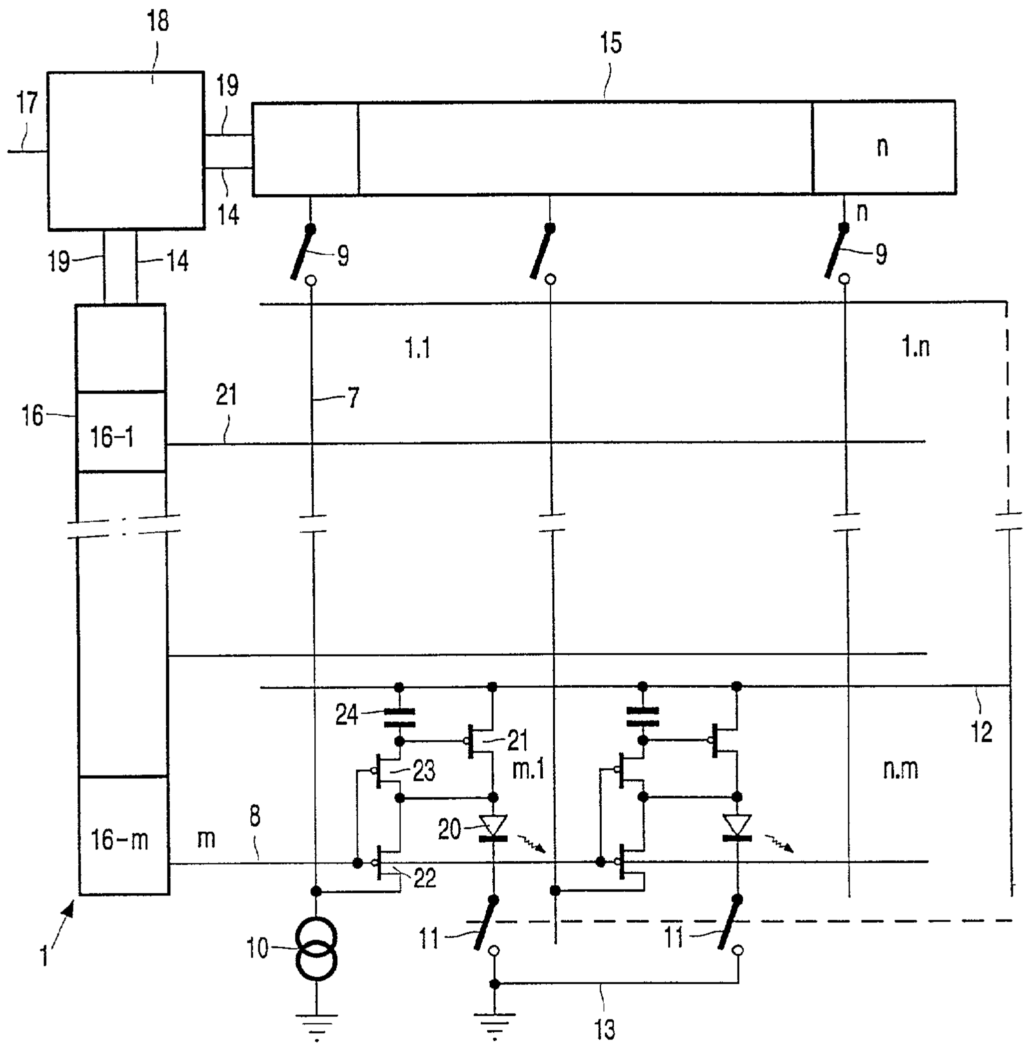
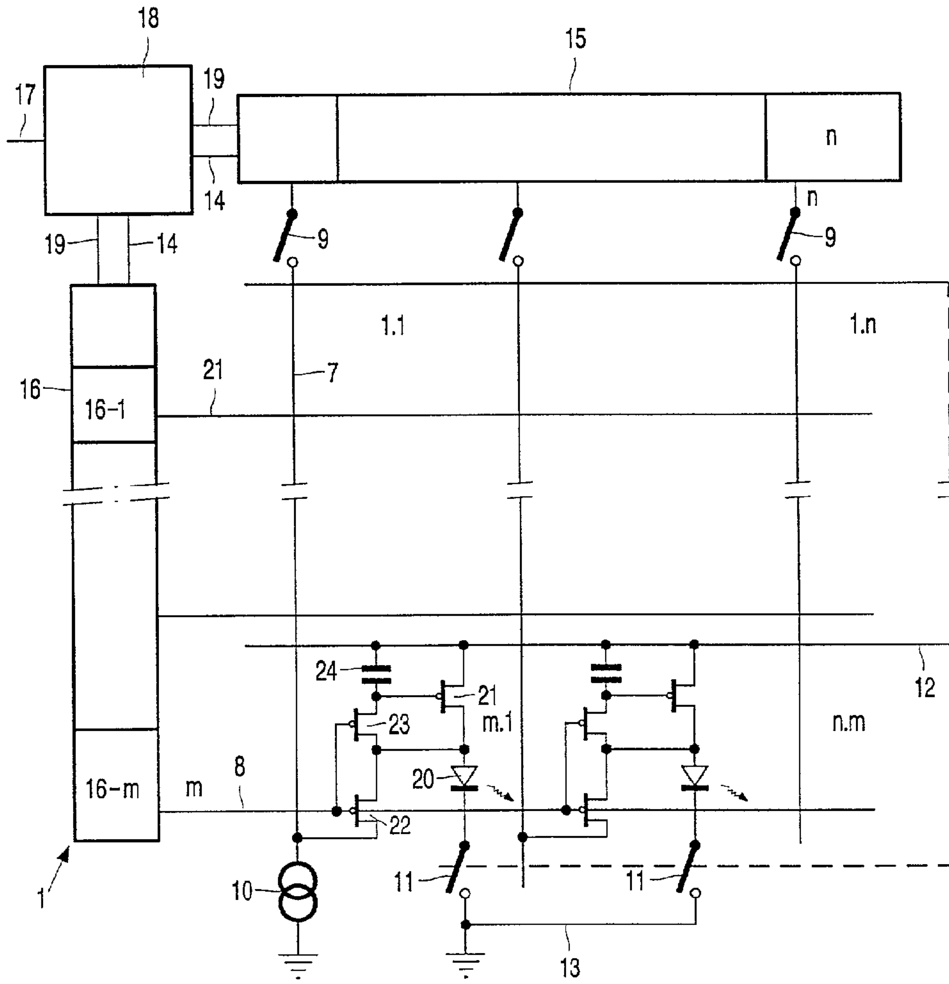
(57) **ABSTRACT**

Grey scal linearity and power efficiently in activ matrix (O) LEDs are enhanced by operating the display in a switched mode.





18
17
19
14
15
n
19
14
9
n
9
16
16-1
21
7
1.1
1.n
24
21
23
m.1
n.m
12
16-m
m
8
20
22
1'
10
11
11
13

FIG. 1

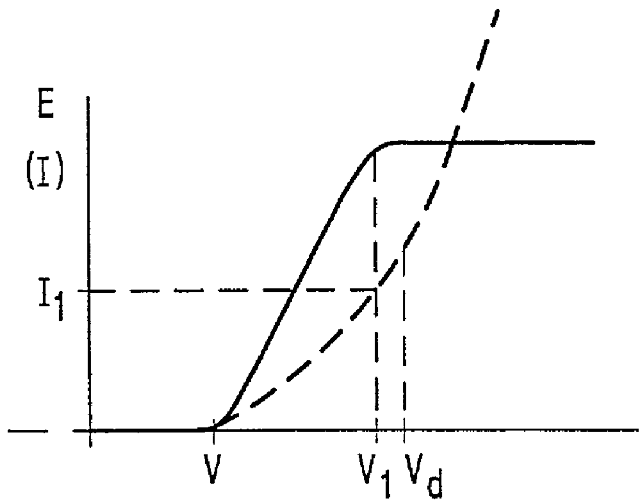


FIG. 2

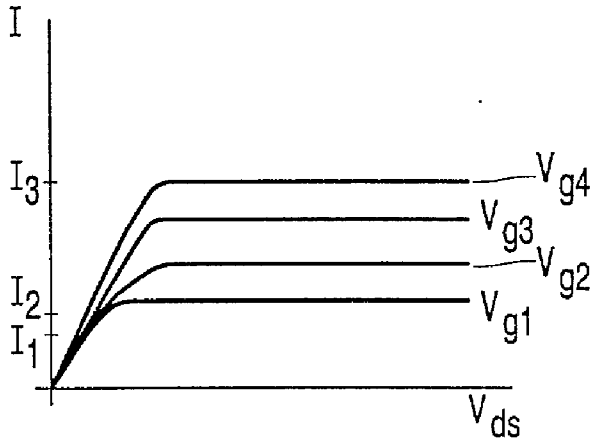


FIG. 3

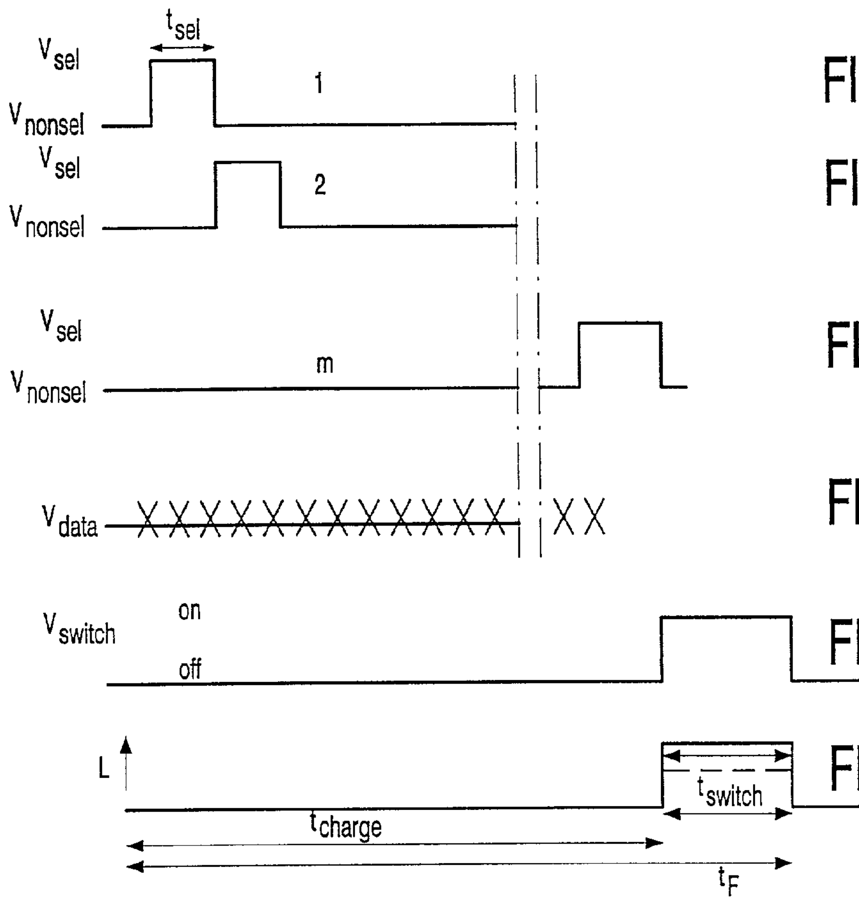


FIG. 4a

FIG. 4b

FIG. 4c

FIG. 4d

FIG. 4e

FIG. 4f

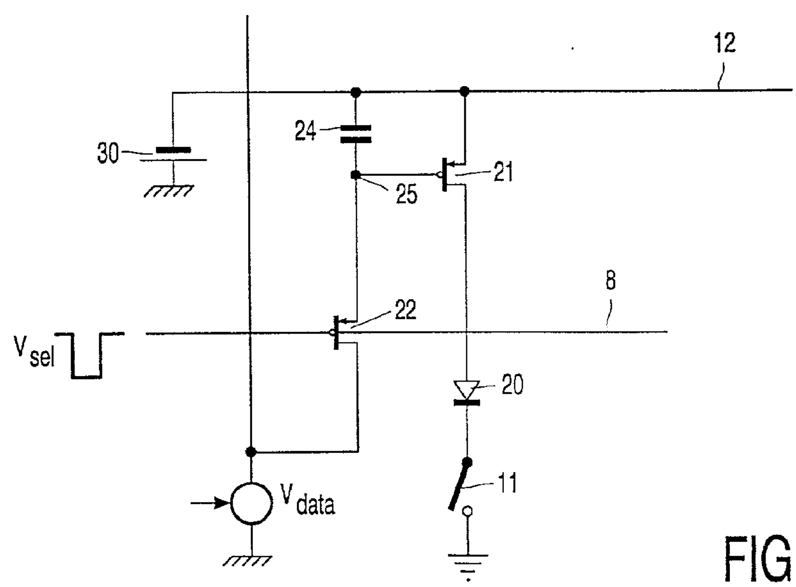


FIG. 5

DISPLAY DEVICE

[0001] The invention relates to a display device comprising a matrix of pixels at the area of crossings of row and column electrodes, each pixel comprising at least a current adjusting circuit based on a memory element, in series with a luminescent element.

[0002] Such electroluminescence-based display devices are increasingly based on (polymer) semiconducting organic materials. The display devices may either luminesce via segmented pixels (or fixed patterns) but also display by means of a matrix pattern is possible. The adjustment of the pixels via the memory element determines the intensity of the light to be emitted by the pixels. Said adjustment by means of a memory element, in which extra switching elements are used (so-called active drive) finds an increasingly wider application.

[0003] Suitable fields of application of the display devices are, for example, mobile telephones, organizers, etc.

[0004] A display device of the type described in the opening paragraph is described in PCT WO 99/42983. In said document, the current through a LED is adjusted by means of two TFT transistors per pixel in a matrix of luminescent pixels; to this end, a charge is produced across a capacitor via one of the TFT transistors. This TFT transistor and the capacitor constitute a memory element. After the first TFT transistor has been turned off, the charge of the capacitor determines the current through the second TFT transistor and hence the current through the LED. At a subsequent selection, this is repeated.

[0005] In this drive mode, the LED conveys current also during non-selection, which is at the expense of dissipation and results in faster ageing. Moreover, artefacts occur in moving images.

[0006] It is, inter alia, an object of the present invention to provide a display device of the type described in the opening paragraph in which the above-mentioned problems occur to a lesser extent. To this end, such a display device is characterized in that the display device comprises at least one independently switchable switch in the current path of the current adjusting circuit and the luminescent element.

[0007] By means of the switch (for example, a TFT transistor or a bipolar transistor), the luminescent elements are provided with a current corresponding to the desired luminance. The adjustment of a part of the drive circuit takes place prior to closing of the switch. Parts of this drive circuit (particularly the combination of a capacitor and a transistor associated with the memory element) are used both for pre-adjustment of a drive value and for determining the ultimate current through the luminescent elements. Since the luminescent elements can now convey current for a much shorter time, they are preferably but not necessarily driven in the so-called constant efficiency range. Here, the efficiency of the LED as a function of the diode voltage is practically constant and the quantity of emitted light is practically linearly proportional to the current through the LED. This provides the possibility of accurately adjusting grey values with a high efficiency so that a short drive pulse of the LEDs is sufficient.

[0008] In a first embodiment, the display device comprises at least a switch in the current path of the current adjusting circuit and the luminescent element. This, however, requires one switch per pixel and is at the expense of the aperture. For this reason, a preferred embodiment is characterized in that the switch is present between a plurality of luminescent elements and a connection point for an operating voltage.

[0009] These and other aspects of the invention are apparent from and will be elucidated with reference to the embodiments described hereinafter.

[0010] In the drawings:

[0011] **FIG. 1** shows diagrammatically a display device according to the invention,

[0012] **FIG. 2** shows the efficiency and the current through a LED as a function of the voltage,

[0013] **FIG. 3** shows transistor characteristics of transistors used in **FIG. 1**, while

[0014] **FIG. 4** shows an associated time diagram, and

[0015] **FIG. 5** shows a further variant.

[0016] The Figures are diagrammatic; corresponding components are generally denoted by the same reference numerals.

[0017] **FIG. 1** shows diagrammatically an equivalent circuit diagram of a part of a display device **1** according to the invention. This display device comprises a matrix of (P) LEDs or (O) LEDs **14** with n rows (1, 2, . . . , n) and m columns (1, 2, . . ., m). Where rows and columns are mentioned, they may be interchanged, if desired. This device further comprises a row selection circuit **16** and a data register **15**. Externally presented information **17**, for example, a video signal, is processed in a processing unit **18** which, dependent on the information to be displayed, charges the separate parts **15-1**, . . . , **15**-n of the data register **15** via supply lines **19**.

[0018] The selection of a row takes place by means of the row selection circuit **16** via the lines **8**, in this example, gate electrodes of TFT transistors or MOS transistors **22**, by providing them with the required selection voltage.

[0019] Writing data takes place in that, during selection, the current source **10**, which may be considered to be an ideal current source, is switched on by means of the data register **15**, for example, via switches **9**. The value of the current is determined by the contents of the data register. The current source **10** may be common for a plurality of rows. If this is not the case, the switches **9** may be dispensed with. Where this application states the phrase "can be electrically coupled to the current source", this case is also considered to be included.

[0020] During addressings, the capacitor **24** is provided with a certain charge via the transistors **21**, **22** and **23**. This capacitor determines the adjustment of the transistor **21** (and constitutes said memory circuit therewith) and hence the actual current through the LED **20** during the drive period, and the luminance of (in this example) the pixel (n,1), as will be described hereinafter. Mutual synchronization between the selection of the rows **8** and the presentation of voltages to the columns **7** takes place by means of the drive unit **18** via drive lines **14**.

[0021] At the instant when a row, in this example row **1**, is selected, the current source **10** starts to convey current.

During selection, information is presented from column register **15** (in this example) via the line **7**. This information determines the current through the (adjusting) transistors **21**, **22** and **23** so that the capacitor **24** acquires a given charge, dependent on the conveyed current and the period of time. The other plate of the capacitor **24** is connected to the positive power supply line **12**. After selection (after closure of the switch **22**), this capacitor has a certain charge which determines the voltage at the gate of (control) transistor **21**. According to the invention, the diode (LED) **20** does not start conducting until after all pixels have been adjusted, i.e. when all transistors **21** have been adjusted in a similar manner. At that instant (at the end of a frame time), a common switch **11** between one or more LEDs **20** and, for example, ground (in this example via the line **13**) is closed for a short time so that current can flow through the transistors **21** and the LEDs **20** so that the LEDs luminesce in conformity with the adjusted value. The switch may also be closed after a part of the number of lines (½, 1/4, . . .) has been written (referred to as sub-frame driving).

[**0022**] The advantage thereof will be described with reference to **FIG. 2**. This Figure shows, as a function of the voltages across a LED, the (logarithm of the) efficiency (solid line) of the LED and the current (broken line) through the LED. The Figure shows that this efficiency reaches a given maximum from a voltage V_1. The current through the LEDs (and hence the luminance) increases substantially exponentially from V_1. Since one or more switches **11** are short-circuited, the desired quantity of light can be emitted for a short time with a high efficiency and a short current pulse.

[**0023**] The adjustable currents preferably have such values that they are practically always larger than the current I_1 (**FIG. 2**) associated with the voltage V_1. To this end, the transistor **21** has a characteristic as is shown in **FIG. 3**. In this embodiment, transistor **21** is a TFT transistor of the p type which, dependent on the gate voltages V_{g1}-V_{g4} supplies currents between I_2 and I_3 (**FIG. 3**), which currents are larger than I_2, while the range I_2-I_3 is sufficiently wide to adjust all grey values in the high efficiency range. The linear current behavior of the (O) LEDs in this range renders a simple adjustment of grey values possible.

[**0024**] The operation of the display device is explained once more with reference to **FIGS. 1 and 4**. By switching on current sources **10** associated with columns 1 to m (**FIG. 4**(*d*)) during consecutive selection of the rows 1 to n (FIGS. **4**(*a*), **4**(*b*), **4**(*c*)), a capacitor **24** is provided with a certain charge in each of the pixels. The information as stored in data register **15** determines, in a way similar to that described above, the current through transistors **21**, **22** and **23**. The voltage on the supply line **12** is such that one plate of the capacitor and hence node **25** receives a voltage in the range V_{g1}-V_{g4}, which voltage is maintained after the current source **10** has been switched off.

[**0025**] The voltage at the node **25** and hence the voltage at the gate of transistor **21** is in the range V_{g1}-V_{g4}. However, the transistor **21** cannot conduct because the switch **11** is opened. This switch is not closed until after the end of the frame period tF after the period t_{charge} in which all pixels are charged. The switch **11** is closed, for example, for a short period t_{switch}, which period is long enough to cause the associated diodes (LED) **20** to luminesce in the correct adjustment. Since all (desired) LEDs are on for a short time with a higher efficiency, there is less degradation in this drive mode than in the customary passive and active structures.

[**0026**] By means of a drive circuit (not shown) the duty cycle

$$\frac{t_{switch}}{t_f}$$

[**0027**] of the switch is adjusted, if desired, as a function of temperature or ageing, such that the efficiency remains substantially constant (optimal). It is also possible to choose the duty cycle to be different per color (in a color display device) and thus to obtain an optimal color point.

[**0028**] The switch **11** is preferably realized in monocrystalline silicon. In this way, a large current required for driving the total number of pixels can be supplied rapidly. This switch may be realized, for example, in a drive IC. Use may also be made of some parallel switches.

[**0029**] **FIG. 5** shows a variant in which the voltage across the capacitor is adjusted by means of voltage control. The voltage across the capacitor **24** (and hence the adjustment of the LED **20**) is now dependent on the voltages from the voltage sources **30**, **31** (V_{data}) and the data voltage $V_{sel.}$

[**0030**] Several variations are of course possible within the scope of the invention. In given applications, not all pixels need to be adjusted in advance before the LED drive is started. A realization with bipolar transistors is also feasible.

[**0031**] The protective scope of the invention is not limited to the embodiments described. The invention resides in each and every novel characteristic feature and each and every combination of features. Reference numerals in the claims do not limit the protective scope of these claims. The use of the verb "to comprise" and its conjugations does not exclude the presence of elements other than those stated in the claims. The use of the article "a" or "an" preceding an element does not exclude the presence of a plurality of such elements.

1. A display device comprising a matrix of pixels at the area of crossings of row and column electrodes, each pixel comprising at least a current adjusting circuit based on a memory element, in series with a luminescent element, characterized in that the display device comprises at least one independently switchable switch in the current path of the current adjusting circuit and the luminescent element.

2. A display device as claimed in claim 1, characterized in that the switch is arranged between the memory element and the luminescent element.

3. A display device as claimed in claim 1, characterized in that the switch is arranged between a plurality of luminescent elements and a connection point for an operating voltage.

4. A display device as claimed in claim 1, characterized in that the memory element and an adjusting circuit for adjusting the grey value have a switch in common.

5. A display device as claimed in claim 1, characterized in that said display device comprises drive means for varying the time during which the independently switchable switch is closed.

6. A color display device as claimed in claim 5, characterized in that the drive means for luminescent elements of different color can close associated independently switchable switches during different periods of time.

7. A display device as claimed in claim 1, characterized in that the luminescent element comprises an organic LED or a polymer LED.

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