

Display device.

The invention relates to a display device comprising an electro-optical display medium between a first and a second supporting plate and provided with rows and column electrodes, which device comprises a plurality of facing first and second picture electrodes arranged on the supporting plates and defining pixels in the electro-optical display medium, a quantity of picture electrodes on the first supporting plate being each connected to a drive electrode or auxiliary electrode *via* a first switching element.

A display device of this type can be used in television applications or data graphic applications.

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A display device of the type described in the opening paragraph is known from USP 4,994,796. This device comprises on one of the supporting plates a picture electrode for each pixel, which picture electrode is connected *via* non-linear switching elements to a row electrode and an electrode for a reference voltage. If the display device is adapted to drive, for example 625 rows and 400 columns, it comprises 250,000 pixels, hence 250,000 switching elements. It is known that defects may occur in the manufacture of these types of switching elements, resulting in an open or short-circuited switching element. To obviate this, redundancy is used in which, for example an extra switching element is arranged between the picture electrode and the column electrode. If one of the two switching elements is short-circuited (this defect occurs most frequently), the short-circuit can be eliminated by means of, for example laser repair resulting in an open connection; the switching function is then performed by one switching element. If one of the two switching elements is open, the switching function is performed by one switching element. In both cases the capacitance of the capacitor associated with the total switching element is approximately halved. (For switching elements in series, this capacitance is approximately doubled if an open connection is short-circuited). This capacitance has great influence on the operation of the display because corrections of row and/or column signals are based thereon in connection with crosstalk and capacitive kick-back. With an equal drive, the repaired pixel will therefore usually have a different transmission level than a pixel which did not need to

be repaired.

In display devices including MIMs, the dropout of one of the MIMs also influences the transmission/voltage behaviour of the relevant pixel.

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It is, *inter alia* an object of the invention to provide a display device in which the above-mentioned drawbacks are obviated as much as possible.

A display device according to the invention is characterized in that the first supporting plate is provided with a second switching element between a first connection
10 connected in an electrically conducting manner to the first switching element and the picture electrode and a second connection between the second switching element and the picture electrode.

Now, the second switching element is not connected to the row or column electrode and in the normal state (unrepaired switching element) there is no voltage drop
15 across the associated capacitor so that the signals at the row or column electrode are only subject to the influence of the capacitor associated with the first switching element. If the first switching element is short-circuited, the connection between the picture electrode and this switching element can be interrupted. The second switching element takes over the function of the first switching element, so that the signals at the row or column electrode are
20 now only subject to the influence of the capacitor associated with the second switching element. Since only one switching element determines the behaviour as regards crosstalk, kick-back or other capacitive effects, both for a repaired and an unrepaired switching element, a more uniform behaviour is obtained.

* The same advantage can be achieved with another embodiment according
25 to the invention. This embodiment is characterized in that the first supporting plate is provided with a second switching element between a first connection connected in an electrically conducting manner to the first switching element and the row electrode and a second connection between the second switching element and the row electrode. In symmetrical switching elements such as MIMs, two extra switching elements for two
30 consecutive rows or columns can advantageously be implemented as one switching element.

To further enhance the repair facilities, the switching elements may be composed of a plurality of switches.

Instead of diodes, as shown in USP 4,994,796, it is alternatively possible to choose MIMs as switching elements and a switching method as described in

USP 5,159,325. The use of TFTs is alternatively possible.

If diodes are used (or more generally, asymmetrical two-pole elements) the picture electrodes are, for example, connected in an electrically conducting manner to the common point of two asymmetrical two-pole elements which are arranged in series between a column electrode and an electrode for a reference voltage; The operation of such a device is described in USP 5,032,831.

A device according to the invention is then characterized in that the first supporting plate is provided with at least one additional asymmetrical two-pole element arranged at the same polarity as the asymmetrical two-pole elements between a first connection connected in an electrically conducting manner to one of the two asymmetrical two-pole elements and the picture electrode and a second connection between the additional asymmetrical two-pole element and the picture electrode.

In this respect the same polarity is understood to mean that the additional asymmetrical two-pole element between the column electrode and the electrode for the reference voltage is arranged in the same direction as the series-arranged two-pole elements.

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

In the drawing

Fig. 1 is a diagrammatical cross-section of a part of a display device according to the invention,

Fig. 2 shows diagrammatically a part of a display device according to the invention,

Figs. 3 and 4 show a further embodiment of a display device according to the invention,

Fig. 5 shows a modification of a part of the device of Fig. 2,

Fig. 6 shows a further modification of a part of a display device according to the invention,

Figs. 7 and 8 are diagrammatic plan views of the parts of the devices of Figs. 2 and 5, while

Fig. 9 shows a different use of the invention, and

Fig. 10 shows a modification of Fig. 9.

The drawings are diagrammatic and not to scale. Corresponding elements

generally have the same reference numerals.

Fig. 1 shows diagrammatically a cross-section of a part of a display device 1 having two supporting plates 2 and 3 between which an electro-optical display medium 4, in this example a liquid crystalline material, is present. The inner surfaces of the supporting plates 2 and 3 are provided with picture electrodes 5 and 6 which, together with the intermediate liquid crystalline material, define a large number of pixels arranged in rows and columns. Strip-shaped row electrodes 7 which are connected to the picture electrodes 5 via non-linear switching elements 8, in this example MIMs, are arranged between the picture electrodes 5. The connections are outside the plane of the drawing and are shown diagrammatically by means of the lines 9. In this example the picture electrodes 6 are integrated with column electrodes 10. The inner surfaces of the supporting plates 2 and 3 further have orienting layers which are not shown. The display device may be further provided with polarizers and can be realised as a transmissive or a reflective device.

Fig. 2 shows diagrammatically a part of such a display device. The pixels 11 are connected via the picture electrodes 6 to the column electrodes 10 which, together with the row electrodes 7, are arranged in the form of a matrix in this example. The pixels 11 are connected to the row or selection electrodes 7 via the picture electrodes 5 and the switching elements (the MIMs 8). An incoming signal 12 is stored via a processing/control unit 13 in a data register 14 which presents the data signals (adapted, if necessary), to the column electrodes 10. This data determines the light transparency to be realised for the pixels 11. To this end the control unit 15 provides the row electrodes with selection signals. The control unit 13 synchronizes the operation of the control unit 15 and the data register 14 via lines 16 and 17.

According to the invention, second switching elements (for example, MIMs 18) are arranged between the picture electrodes 5 and the connections of the switching elements 8 connected to the picture electrodes 5. If a switching element 8 functions satisfactorily, a pixel 11 is charged or discharged via the current path 19 during operation. Since the second switching element 18 is short-circuited, as it were, there is no voltage across the second switching element, hence no voltage across the associated capacitor. The presence of the redundant switching element 18 thus hardly influences or has no influence on phenomena such as crosstalk and kick-back and will consequently not influence a good transmission setting.

If a switching element 8 does not function satisfactorily, it is short-circuited by means of laser repair so that a short-circuit path 20 is created; moreover, the connection 21 is interrupted, for example by means of "laser cutting". For the defect which occurs most frequently, viz. short-circuit of the switching element 8, only the connection 21 is to be interrupted. During operation, a pixel 11 is charged or discharged *via* the current path 22. Since the second switching element 18 takes over the function of switching element 8 and has substantially the same characteristics, the influence on phenomena such as crosstalk and kick-back is substantially the same.

Fig. 3 shows an embodiment in which the extra switching element 18, in this case a MIM, is short-circuited by the row electrode 7. Since the MIM has a symmetrical current/voltage behaviour, the number of additional switching elements 18 can be halved, as is shown in Fig. 4. The additional MIM 18 can now be employed when either the MIM 8, or when the MIM 8' is defective. The MIM 18 may comprise a plurality of switches. From a layout-technical point of view, the embodiment of Fig. 4 can be implemented in such a favourable manner that a larger aperture is obtained than in the example shown in Fig. 2.

Fig. 5 shows diagrammatically a modification of a part of the device of Fig. 2. Now, the switching elements 8, 18 are composed of sub-elements (in this example MIMs) 8^a, 8^b, 18^a, 18^b. At a short-circuit of one of the MIMs 8, the circuit will continue to function. To obtain an identical behaviour of a repaired and an unrepaired pixel with respect to its voltage/current behaviour, the two MIMs 8 are, however, preferably short-circuited, while the branch with the MIMs 18 is switched on; at a short-circuit of the two MIMs 8, the branch with the MIMs 18 (which may also be limited to one MIM) can be switched on similarly as described hereinbefore. For an open connection due to non-functioning of one of the MIMs 8, this MIM can be short-circuited and the other MIM will continue to function. If the defective MIM cannot be detected in this case, a short-circuit path 20 can be provided, similarly as in the case where the two MIMs have an open connection, while the connection 21 is opened.

Fig. 6 shows an embodiment in which TFTs are used as switching elements. Row and column electrodes 7 and 10 are now provided on a supporting plate, while a counter-electrode 6 which is common for the pixels 11 is present on the other supporting plate, which counter-electrode is connected to ground in this case. If there is a defect in TFT 23, the connections of this transistor can be modified again in such a way that its function is taken over by transistor (TFT) 24.

Figs. 7 and 8 show plan views of possible realisations of the circuits of

Figs. 2 and 5, respectively. The supporting plate 2 is provided (in this example) with a transparent electrode pattern of, for example indium-tin oxide; this pattern comprises picture electrodes 5 and strips 25. A layer of an insulating material, for example silicon nitride is provided and patterned across a part of the strips and the picture electrodes, which is shown by means of broken lines 26 in Figs. 7 and 8. Finally, a metallization pattern is provided, which comprises the row electrodes 7 and strips 27. At locations where the strips 27 overlap the indium-tin oxide, the overlapping parts, either together with the intermediate silicon nitride, constitute the MIMs 8, 18, or (at locations where no silicon nitride has been provided) form mutual contacts. The contacts may form part of the connection 21. In addition, similar contacts at the area of the row electrodes constitute the contacts of these row electrodes and the MIMs so that a safeguard against open row electrodes and a decrease of the row resistance is obtained.

Fig. 9 shows an embodiment in which a pixel 11 is connected in an electrically conducting manner to the common point of series-arranged diodes 8, 8' between a column electrode 10 and an electrode 29 for a reference voltage. The operation of such a circuit is described in USP 5,032,831. The device comprises additional diodes 18, 18' which may be switched on when one of the diodes 8, 8' is short-circuited.

If necessary, the function of the diodes 18, 18' can be fulfilled by one diode, as is shown in Fig. 10. If the diode 8 (8') in Fig. 10 is short-circuited, the connection 30 (30') is interrupted by means of laser cutting and diode 18 takes over the function of the short-circuited diode.

Claims:

1. A display device comprising an electro-optical display medium between a first and a second supporting plate and provided with row and column electrodes, which device comprises a plurality of facing first and second picture electrodes arranged on the supporting plates and defining pixels in the electro-optical display medium, a quantity of picture electrodes on the first supporting plate being each connected to a drive electrode or auxiliary electrode *via* a first switching element, characterized in that the first supporting plate is provided with a second switching element between a first connection connected in an electrically conducting manner to the first switching element and the picture electrode and a second connection between the second switching element and the picture electrode.
- 10 2. A display device comprising an electro-optical display medium between a first and a second supporting plate and provided with row and column electrodes, which device comprises a plurality of facing first and second picture electrodes arranged on the supporting plates and defining pixels in the electro-optical display medium, a quantity of picture electrodes on the first supporting plate being each connected to a drive electrode or auxiliary electrode *via* a first switching element, characterized in that for at least a picture electrode the first supporting plate is provided with a second switching element between a first connection connected in an electrically conducting manner to a short-circuited first switching element and a second connection between the second switching element and the picture electrode, the electrical connection between the short-circuited first switching element and the picture⁹ electrode being interrupted.
- 15 3. A display device comprising an electro-optical display medium between a first and a second supporting plate and provided with row and column electrodes, which device comprises a plurality of facing first and second picture electrodes arranged on the supporting plates and defining pixels in the electro-optical display medium, a quantity of picture electrodes on the first supporting plate being each connected to a drive electrode or auxiliary electrode *via* a first switching element, characterized in that the first supporting plate is provided with a second switching element between a first connection connected in an electrically conducting manner to the first switching element and the row electrode and a second connection between the second switching element and the row electrode.
- 20 4. A display device comprising an electro-optical display medium between a



first and a second supporting plate and provided with row and column electrodes, which device comprises a plurality of facing first and second picture electrodes arranged on the supporting plates and defining pixels in the electro-optical display medium, a quantity of picture electrodes on the first supporting plate being each connected to a drive electrode or auxiliary electrode *via* a first switching element, characterized in that for at least a picture electrode the first supporting plate is provided with a second switching element between a first connection connected in an electrically conducting manner to a short-circuited first switching element and a second connection between the second switching element and the row electrode, the electrical connection between the short-circuited first switching element and the row electrode being interrupted.

5. A display device as claimed in Claim 3, characterized in that in a row the second switching element is common for two pixels in successive columns.

6. A display device as claimed in Claim 1, 2, 3, 4 or 5, characterized in that at least one of the switching elements comprises a plurality of switches.

15 7. A display device as claimed in any one of Claims 1 to 6, characterized in that the switching elements or switches are MIMs.

8. A display device comprising an electro-optical display medium between a first and a second supporting plate and provided with row and column electrodes, which device comprises a plurality of facing first and second picture electrodes arranged on the supporting plates and defining pixels in the electro-optical display medium, a quantity of picture electrodes on the first supporting plate being each connected in an electrically conducting manner to the common point of two asymmetrical two-pole elements which are arranged in series between a column electrode and an electrode for a reference voltage, characterized in that the first supporting plate is provided with at least one additional asymmetrical two-pole element arranged at the same polarity as the asymmetrical two-pole elements between a first connection connected in an electrically conducting manner to one of the two asymmetrical two-pole elements and the picture electrode and a second connection between the additional asymmetrical two-pole element and the picture electrode.

25 9. A display device comprising an electro-optical display medium between a first and a second supporting plate and provided with row and column electrodes, which device comprises a plurality of facing first and second picture electrodes arranged on the supporting plates and defining pixels in the electro-optical display medium, a quantity of picture electrodes on the first supporting plate being each connected in an electrically conducting manner to the common point of two asymmetrical two-pole elements which are



arranged in series between a column electrode and an electrode for a reference voltage, characterized in that for at least a picture electrode the first supporting plate is provided with an additional asymmetrical two-pole element arranged at the same polarity as the asymmetrical two-pole elements between a first connection connected in an electrically
5 conducting manner to a short-circuited switching element of one of the two asymmetrical two-pole elements and a second connection between the additional asymmetrical two-pole element and the picture electrode, the electrical connection between the short-circuited asymmetrical two-pole element and the picture electrode being interrupted.

10. A display device as claimed in Claim 1, 2 or 3, characterized in that the
10 switching elements or switches are thin-film transistors (TFTs).

11. A display device as claimed in Claim 7, characterized in that gate
electrodes of the thin-film transistors are connected in an electrically conducting manner to row electrodes, while the source electrodes of the first thin-film transistors associated with a plurality of picture electrodes are connected in an electrically conducting manner to column
15 electrodes and the drain electrodes are connected in an electrically conducting manner to the picture electrodes and to source electrodes of second thin-film transistors associated with the picture electrodes, which second thin-film transistors have their drain electrodes connected in an electrically conducting manner to the picture electrodes.