350-332 SR
XR 3,781,865

United State

Yamazaki

[11] 3,781,865
[45] Dec. 25, 1973

[54] DISPLAY DEVICE FOR ELECTRONIC DESK CALCULATOR

[75] Inventor: Yoshio Yamazaki, Suwa, Japan

[73] Assignee: Kabushiki Kaisha Suwa Seikosha, Tokyo, Japan

[22] Filed: Mar. 20, 1972

[21] Appl. No.: 236,294

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 44,839, June 9, 1970, abandoned.

[30] Foreign Application Priority Data

June 21, 1969 Japan 44/48679

[52] U.S. Cl. ..... 340/336, 340/324 R, 350/160 LC
[51] Int. Cl. G08b 5/36
[58] Field of Search ..... 340/324 R, 336; 350/160 LC

[56] References Cited

UNITED STATES PATENTS

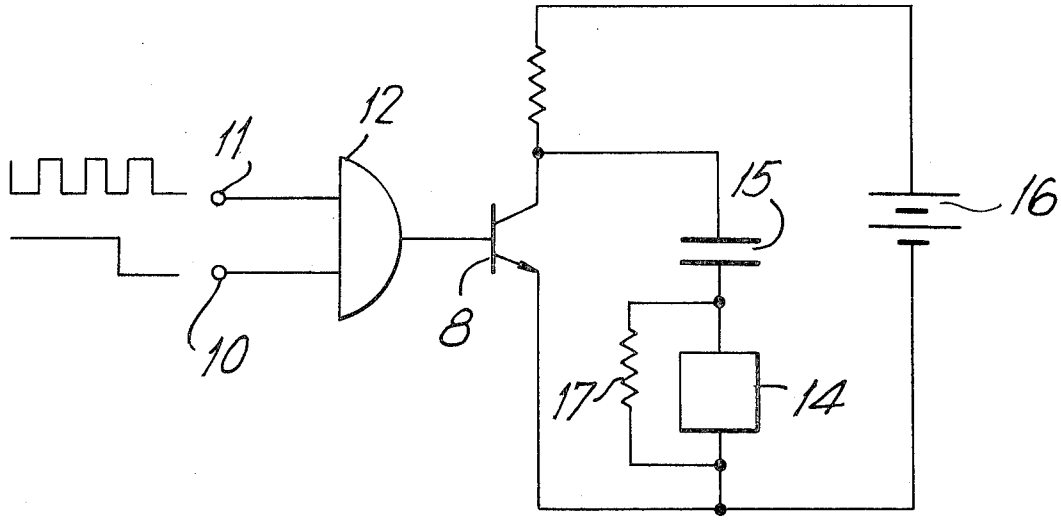
3,357,010	12/1967	Sweeney	340/336 X
3,505,804	4/1970	Hofstein	340/336 X
3,551,689	12/1970	Zanoni	340/324 R UX
3,575,491	4/1971	Heilmeier	350/160 LC

Primary Examiner—David L. Trafton
Attorney—Alex Friedman et al.

[57] ABSTRACT

A display device for an electronic desk calcuator incorporating liquid crystals of the nematic phase which cause light scattering when AC or DC voltages are applied thereto. Driving circuits are provided for applying an AC driving voltage to a display incorporating said liquid crystals.

8 Claims, 6 Drawing Figures



3781865
OR IN 340/336

FIG. 1

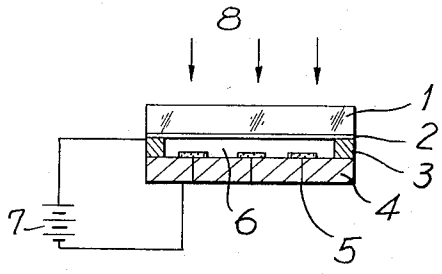


FIG. 2

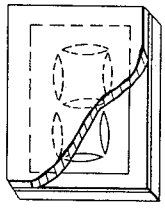


FIG. 3

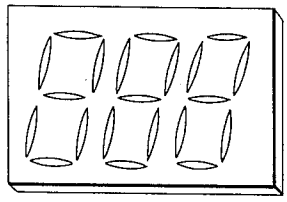


FIG. 4

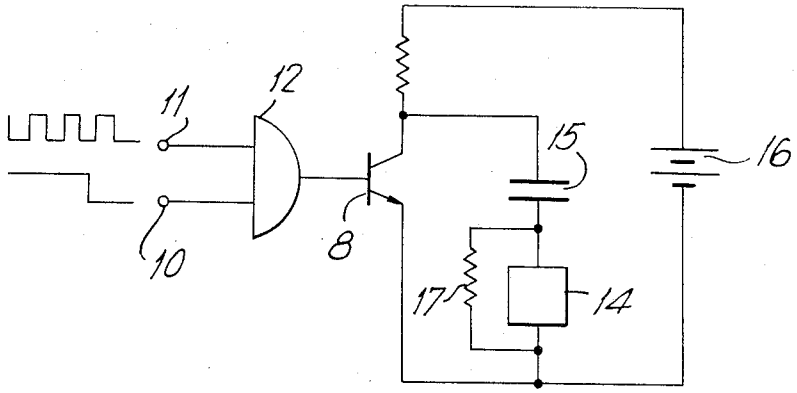


FIG. 5a

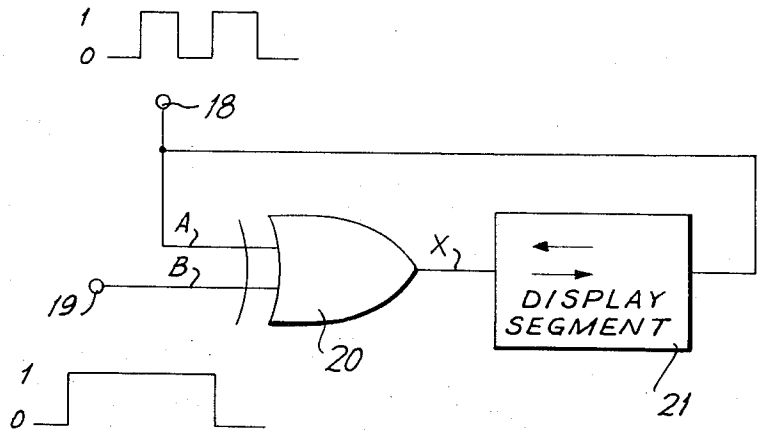


FIG. 5b

$X = \bar{A} \cdot B + A \cdot \bar{B}$

A	B	X
0	0	0
1	0	1
0	1	1
1	1	0

DISPLAY DEVICE FOR ELECTRONIC DESK CALCULATOR

BACKGROUND OF THE INVENTION

This is a continuation-in-part application of U. S. Pat. application Ser. No. 44,839, filed June 9, 1970 now abandoned.

This invention relates to electronic desk calculators, and in particular, to electronic desk calculators incorporating a display device including liquid crystal material.

Display devices for electronic desk calculators such as the Burroughs display tube and the vacuum tube (Digitron) are well known in the art. In such systems, gases in vacuum tubes emit their own light so that the display is easily read in dark surroundings. However, as the surroundings become brighter, the contrast between the numbers on the display tube and the surrounding light decreases, and the display substantially dulls. However, electronic calculators are generally used in bright rooms. This necessitates the mounting of the display tube of the current electronic desk calculators at the lowest part of the display panel to provide relatively dark surroundings.

SUMMARY OF THE INVENTION

Generally speaking, in accordance with the invention, a display device for an electronic desk calculator is provided having a pair of spaced plates at least one of which is transparent. A common conductive electrode is mounted on the inside surface of one of the plates while a segmented electrode is mounted on the inner surface of the other of said plates in facing relation to said common electrode. The segmented electrode includes a plurality of segments, various combinations of which define the numbers zero–nine in at least two columns. At least the one of said common and segmented electrodes mounted on said transparent plate is also transparent. A nematic liquid crystal material is retained between said plates and selected to cause light scattering when a predetermined voltage supplied between said common and segmented electrodes.

A driving circuit for said display is connected between each segment of said segmented electrodes and said common electrode. Each said driving circuit includes switch means for applying an alternating voltage between said electrodes when the region of said liquid crystal adjacent said segmented electrodes is to be rendered visible. Said switch means preferably includes gate means for controlling the application of an alternating driving voltage to said display electrodes, said gate means having an intermittent pulse signal and a display actuation signal applied thereto, and being adapted to permit the driving of said display by said alternating voltage when said actuation signal is in a predetermined state.

Accordingly, it is an object of this invention to provide an electronic desk calculator incorporating a liquid crystal display device.

Another object of the invention is to provide an electronic desk calculator incorporating a liquid crystal display device driven by an AC voltage.

Still another object of the invention is to provide an electronic desk calculator incorporating driving circuit means adapted to drive a liquid crystal display device by an alternating voltage.

Still other objects and advantages of the invention will in part be obvious and will in part be apparent from the specification and drawings.

The invention accordingly comprises the features of construction, combinations of elements, and arrangement of parts which will be exemplified in the constructions hereinafter set forth, and the scope of the invention will be indicated in the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

For a fuller understanding of the invention, reference is had to the following description taken in connection with the accompanying drawings, in which:

FIG. 1 is a cross sectional view of the liquid crystal display device in accordance with the invention;

FIG. 2 is a partially sectioned schematic view of one embodiment of the display device in accordance with the invention;

FIG. 3 is a schematic representation of a display device according to the invention incorporating a plurality of columns;

FIG. 4 is a circuit diagram of one embodiment of the driving circuit for the liquid crystal displays in accordance with the invention;

FIG. 5*a* is a circuit diagram of a second embodiment of the driving circuit for the liquid crystal displays in accordance with the invention; and

FIG. 5*b* is a truth table depicting the operation of the exclusive OR gate of the circuit of FIG. 5*a*.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Liquid crystal materials are in a mesomorphic state between liquid and solid within a certain temperature range. In other words, such materials are a group of organic compounds chemically anisotropic and having solid crystal characteristics in fluid form.

Liquid crystal materials are classified into three groups, namely nematic, smectic and cholesteric. Particularly in some of nematic liquid crystal materials, the molecular arrangement is analogous to a long box filled with round pencils which can roll around and slide back and forth. Molecules are oriented and dipoles are arranged in the direction of the electric field when an AC or DC voltage is applied thereto. Since the molecules constituting a nematic liquid crystal material are of a long shape, some remain in their initial position without rotating. The reflecting ratio of the boundary portion is different from that of the interior due to the anisotropy of double reflection. As a result, the scattering of light in the liquid crystal material can be observed by the naked eye.

Display devices incorporating liquid crystal may be formed in the manner depicted in FIGS. 1 and 2. Numbers are digitally displayed by means of a seven-bar display. The display is formed by sandwiching liquid crystal material between a base plate and transparent conductive electrodes from which lead wires are taken out. The display may have only a single column or digit as depicted in FIG. 2, or may have a plurality of columns or digits as depicted in FIG. 3. Where a liquid crystal display device such as that depicted in FIGS. 1 – 3 is incorporated in an electronic desk calculator, the display can be clearly read in bright surroundings due to the unique characteristics of the liquid crystal material. As noted above, a nematic liquid crystal material sealed in the display device causes light scattering due to the

double reflection of light as the transmission coefficient of light changes due to the application of an electric field thereto. The larger the incident light, the greater the scattering effect, which results in clear contrast of the numbered displayed. Accordingly, when the liquid crystal display device is utilized, it is unnecessary to provide a cover on the display device to darken the surrounding area.

The display device in accordance with the invention may be formed so that the liquid crystal substrate is sandwiched between thin plates carrying the required conductive electrode. By this method, a very thin and compact display device can be produced. This permits the production of the compact electronic desk calculators for which there is a great demand.

Unlike the vacuum tube arrangements such as the Burroughs display tube and the digitron discharge tube, the liquid crystal display device does not require vacuum-tight sealing techniques. Further, a display device having a number of columns, as well as a device having only a single column can be readily manufactured in the same simple manufacturing process. The provision of a plurality of columns of one display plate improves not only the design but the legibility. This arrangement eliminates the defect of the above-mentioned vacuum tube arrangement formed with a plurality of character elements, one of said character elements being associated with each number from zero–nine, wherein legibility is decreased due to the distance between the character elements on the front of the vacuum tube and that on the rear side thereof.

Referring now to FIG. 1, one embodiment of the display device incorporating liquid crystal materials for application to electronic desk calculators in accordance with the invention is depicted. In said embodiment, liquid crystal material 6 of the nematic phase and an insulating spacer 3 are sandwiched and sealed between a transparent plate 1 having a transparent conductive electrode film 2 such as tin oxide deposited thereon, and an insulating substrate 4 having a block of conductive electrodes 5 evaporated on the surface thereof. By connecting the transparent conductive film 2 and the block of conductive electrodes 5 to a battery 7 to apply a driving voltage therebetween, the portion of the liquid crystal material 6 sandwiched therebetween scatters the light 8 applied thereto from the outside. In the usual circumstance, a separate lead would be connected to each segmented electrode of the block of conductive electrodes 5 for the separate and selective energization thereof to provide the digital display of the desired number. The segments of the segmented display would be aligned and oriented in the seven-bar configuration as depicted in FIG. 2. Where a plurality of columns are provided, as shown in FIG. 3, only a single transparent conductive electrode would be provided to minimize the number of lead wires required. Similarly, only one insulating spacer placed between the transparent plate and the substrate is sufficient, the specific columns being defined by separate arrays of segmented electrodes.

Referring now to FIG. 4, a circuit diagram of one embodiment of a driving circuit for the display device of an electronic calculator in accordance with the invention is depicted. In said circuit, the display actuation signal is applied to input terminal **10**, the state of said signal being representative of whether the particular liquid crystal segments to which the driving device is connected is to be rendered visible. An intermittent pulse signal of a frequency of over 60 Hz is applied to input terminal **11**. Input terminals **10** and **11** define the inputs to AND gate **13**, the output of said AND gate being applied to the base of a transistor **13** which drives the liquid crystal display element **14**. A DC battery **16** is connected in series with a resistor, condenser **15** which serves to cut off the flow of direct current, and the liquid crystal display element **14**. The two terminals of a liquid crystal display element would be defined, for example, by the common electrode **2** and one segment of the block of electrodes **5**. The emitter-collector path of transistor **13** is connected between said resistor and the liquid crystal display element **14**.

When a display actuation signal of the proper state enters terminal **10**, the intermittent pulse signal is applied to the base of driving transistor **13** by AND gate **12**. By setting the peak voltage of said pulse signal at the operating level of transistor **13**, an alternating voltage is applied to the electrodes of display element **14**. Condenser **15** serves to prevent the aging of molecular activity in the liquid crystal by applying the positive and negative charges to the liquid crystal but avoiding the application of DC current. Resistor **17** is connected in parallel with display element **14** and serves to lower the high internal impedance of the liquid crystal display element. Without resistor **17**, segments of the display other than the desired segment may be actuated due to the too high internal impedance of the liquid crystal when operated on by the electrical driving circuit.

A second embodiment of the driving circuit for applying an AC driving voltage to liquid crystal display elements is depicted in FIG. *5a*, wherein an intermittent pulse signal is applied to input terminal **18** and the display activation signal is applied to input terminal **19**. Input terminal **18** is connected to one electrode of display segment **21**, the other electrode of said display segment being connected to the output of exclusive OR gate **20**. The two inputs of exclusive OR gate **20**, inputs A and B, are respectively defined by the signals applied to terminals **18** and **19**.

The output X of exclusive OR gate **20** may be represented by the following formula, illustrated in the truth table of FIG. *5b*:

$$X = \overline{A} \cdot B + A \cdot \overline{B}$$

Where the display actuation signal applied to terminal **19** is positive, the display segment **21** should be actuated. In this case, if intermittent pulse signal **18** is also positive, output X is negative, while if intermittent pulse **18** is negative, output X is positive. In both cases, a potential difference is produced across electrodes of display segment **21** and said liquid crystal display segment is turned on.

In the case where the display actuation signal **19** is negative, display segment **21** should not be turned on. In such a case, when intermittent pulse **18** is positive, output X is positive, while when intermittent pulse **18** is negative, output X is negative. Under both conditions, the electric potentials at both electrodes of display segment **21** are the same and said liquid crystal display segment is not turned on.

Accordingly, by the foregoing arrangement, the liquid crystal display element can be driven by applying an alternating electric field. The operation of the liquid crystal display device in accordance with the invention by an alternating electric field, as compared to driving

said electronic calculator by a direct voltage, offers the following advantages:

1. Where the alternating voltage is applied, the initial display effect is maintained without discoloration or deterioration in quality over a period of time. In liquid crystal display devices driven by direct voltages, deterioration appears on the fourth day after starting operations.

2. Where a display device is driven by a direct voltage, the electrolysis of the moisture contained in the liquid crystal material causes bubbles of hydrogen and oxygen to be formed which causes the deterioration of the device by the second day. This effect does not occur where alternating voltages are applied.

3. Further, during the electrolysis effect, foreign matter adheres to the electrodes of the display devices driven by direct voltage, an effect not found where an alternating voltage is applied.

The application of the liquid crystal display device in accordance with the invention to electronic desk calculators offers the following advantages over the prior art arrangements:

1. The display device is extremely thin, which results in simple structure, easy design and low cost. 2. Due to the characteristics of the liquid crystal material, the brighter the surroundings, the clearer the contrast of the characters as against the background of the display.

3. Legibility is substantially increased as the numbers are arranged in a single plane.

4. The simple structure enables the use of simple manufacturing techniques for the manufacture of a display incorporating a plurality of digits on a single substrate.

It will thus be seen that the objects set forth above, and those made apparent from the preceding description, are efficiently attained and, since certain changes may be made in the above constructions without departing from the spirit and scope of the invention, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

It is also to be understood that the following claims are intended to cover all of the generic and specific features of the invention herein described, and all statements of the scope of the invention which, as a matter of language, might be said to fall therebetween.

What is claimed is:

1. In an electronic desk calculator, the improvement which comprises a pair of spaced plates, at least one of which is transparent; a common conductive electrode mounted on the inside surface of one of said plates; a segmented electrode mounted on the inner surface of the other of said plates in facing relation to said common electrode, said segmented electrode including a plurality of segments, various combinations of which defines the numbers zero–nine in at least two columns, the one of said common and segmented electrodes mounted on said transparent plate being transparent; nematic liquid crystal material retained between said plates and selected to cause an activated state when a predetermined voltage is applied between said common and segmented electrodes; driving circuit means connected to at least one of said segmented electrodes and said common electrode, each said driving circuit means including gate means for controlling the application of an alternating voltage between said electrodes when the region of said liquid crystal adjacent said segmented electrode is to be rendered visible, said gate means having a pair of inputs for receiving a display actuation signal when the region of the segmented electrode to which said gate means is connected is to be rendered visible, and an intermittent pulse signal.

2. An electronic desk calculator as recited in claim 1, including driving circuit means connected to at least one of said segmented electrodes and said common electrode, each said driving circuit means including gate means for controlling the applicaton of an alternating voltage between said electrodes when the region of said liquid crystal adjacent said segmented electrode is to be rendered visible.

3. An electronic desk calculator as recited in claim 2, wherein said gate means has a pair of inputs for receiving a display actuation signal when the region of the segmented electrode to which said gate means is connected is to be rendered visible and an intermittent pulse signal.

4. In an electronic desk calculator, the improvement which comprises a pair of spaced plates, at least one of which is transparent; a common conductive electrode mounted on the inside surface of one of said plates; a segmented electrode mounted on the inner surface of the other of said plates in facing relation to said common electrode, said segmented electrode including a plurality of segments, various combinations of which defines the numbers zero–nine in at least two columns, the one of said common and segmented electrodes mounted on said transparent plate being transparent; nematic liquid crystal material retained between said plates and selected to cause an activated state when a predetermined voltage is applied between said common and segmented electrodes; driving circuit means connected to at least one of said segmented electrodes and said common electrode, each said driving circuit means including gate means for controlling the application of an alternating voltage between said electrodes when the region of said liquid crystal adjacent said segmented electrode is to be rendered visible, said gate means having a pair of inputs for receiving a display actuation signal when the region of the segmented electrode to which said gate means is connected is to be rendered visible, and an intermittent pulse signal; and a DC voltage source, said gate means further including an AND gate incorporating said pair of inputs, and having an output; and switch means adapted for selective placement in either a conductive or non-conductive state in response to the signal from said AND gate output, said switch means being placed in a conductive state by the intermittent pulse signal passed by said AND gate when said display actuation signal is applied to one input of said AND gate and being placed in a non-conductive state in response to the absence of an output signal from said AND gate in the absence of a display actuation signal applied to said AND gate, said segmented and common electrodes being connected in parallel to said switch means, so that an alternating voltage is applied to said electrodes in response to said display actuation signal.

5. An electronic desk calculator as recited in claim 4, wherein said switch means includes a transistor having a base, emitter and collector, said AND gate output being connected to the base of said transistor, the emitter-collector path of said transistor being connected in parallel with said segmented and common electrodes and in series with said DC voltage source.

6. An electronic calculator as recited in claim 5, including capacitor means in series with said common and segmented electrodes, said series connection being in parallel with said transistor emitter-collector path.

7. An electronic calculator as recited in claim 5, including resistor means connected in parallel with said segmented and common electrodes, said resistor means being of a value selected to lower the high internal impedance of the liquid crystal.

8. In an electronic desk calculator, the improvement which comprises a pair of spaced plates, at least one which is transparent; a common conductive electrode mounted on the inside surface of one of said plates; a segmented electrode mounted on the inner surface of the other of said plates in facing relation to said common electrode, said segmented electrode including a plurality of segments, various combinations of which defines the numbers zero–nine in at least two columns, the one of said common and segmented electrodes mounted on said transparent plate being transparent; nematic liquid crystal material retained between said plates and selected to cause an activated state when a predetermined voltage is applied between said common and segmented electrodes; and driving circuit means connected to at least one of said segmented electrodes and said common electrode, each said driving circuit means including gate means for controlling the application of an alternating voltage between said electrodes when the region of said liquid crystal adjacent said segmented electrode is to be rendered visible, said gate means having a pair of inputs for receiving a display actuation signal when the region of the segmented electrode to which said gate means is connected is to be rendered visible, and an intermittent pulse signal, said gate means further including an exclusive OR gate including said pair of inputs and having an output connected to one of said common and segmented electrodes, the other of said common or segmented electrodes being connected to receive said intermittent pulse signal, so that an alternating voltage is supplied to said electrodes in response to said display actuation signal.

* * * * *