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(54) IMPROVEMENTS IN OR RELATING TO LIQUID CRYSTAL DISPLAY APPARATUS

(71) We, KABUSHIKI KAISHA SUWA SEIKOSHA, a Japanese company of 3-4, 4-chome, Ginza, Chuo-ku, Tokyo, Japan, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to liquid crystal display apparatus and though not limited exclusively to its application thereto, is primarily intended for and is of great advantage when applied to electronic clocks, watches and other timepieces of the kind in which time is displayed numerically in figures by liquid crystal display means.

The invention is illustrated in and explained in connection with the accompanying drawings, in which:—

Figures 1*a* and 1*b* show a numerically indicating liquid crystal device as known per se;

Figures 2*a* and 2*b* show diagrammatically a typical known D.C. driving arrangement for a device as illustrated by Figures 1*a* and 1*b*;

Figure 3*a* is a diagram of one form of A.C. driving arrangement in accordance with this invention for providing A.C. drive to a device as illustrated by Figures 1*a* and 1*b*,

Figure 3*b* is a graphical explanatory figure explanatory of the operation of the arrangement of Figure 3*a*,

Figure 4 shows, in manner similar to Figure 3*a*, a modified arrangement in accordance with the invention, and

Figure 5 is a block diagram of an electronic wrist watch in accordance with the present invention.

Figure 1 (*a* and *b*) are mutually perpendicular views of a typical liquid crystal numeric display device comprising seven elements, Figure 1*a* being a plan view and Figure 1*b* a cross-sectional view. To simplify the drawing the external connections are omitted. Referring to Figure 1 there is an upper panel 1 on which are (in this case) seven electrode elements arranged as shown in such manner that, by energising different combinations thereof, any numeral between 0 and 9 can be displayed. The elements are referenced *a*, *b*, *c*, *d*, *e*, *f* and *g* and, for example, by causing the elements *a*, *b*, *g*, *e* and *d* to light up, the numeral 2 can be displayed. The electrode material is usually tin oxide. 2 is a lower panel, on the surface of which is a common counter electrode P. Liquid crystal 3 fills the shallow space between the electrode system *a* to *g* and the common counter electrode P, being retained by a sealing peripheral spacer 4. If a suitable potential is applied between a selected one of the electrodes *a* to *g* and the counter electrode P the liquid crystal between the electrodes in question manifests irregular light reflections so that the selected electrode "lights up" i.e. is picked out in reflected light.

Figure 2*a* is a diagram of a typical conventional driving circuit for a liquid crystal display device as shown in Figure 1. Block D represents any known form of decoder and output circuit arrangement composed of complementary field effect transistors. For the sake of brevity complementary field effect transistors will hereinafter be referred to as "C-mos" in which "C" stands for complementary and "mos" has the customary meaning. It provides, in response to input driving signals in a BCD (binary coded decimal) code, output signals which appear at the terminals marked *a'* to *g'*. The electrodes *a* to *g* of Figure 1 are connected the corresponding referenced terminals. Each element of the display device is represented in Figure 2*a* by a capacity C (the effective capacity presented at an electrode *a*, *b*, *c*, *d*, *e*, *f* or *g* as the case may be) in parallel with a resistance R due to the ohmic re-

sistance of the liquid crystal. Each shunt combination of capacity C and resistance R is connected between the appropriate one of the terminals *a'* to *g'* and the common counter electrode which is represented by the line P in Figure 2*a* and is earthed. If, for example, the BCD code input in Figure 2*a* is appropriate to the numeral 2 potentials will appear at terminals *a'*, *b'*, *g'*, *e'*, and *d'* and the numeral 2 will be displayed in light. Operating supply potential is applied at V_{DD}.

Figure 2*b* shows an example of the structure of one of the output circuits (which are all similar) of the decoder. It comprises an inverter consisting of a pair of C-MOS type transistors as shown, and its output, taken from the appropriate one of the terminals *a'* to *g'* either V_{DD} or earth potential, depending on the BCD code input. Because a C-MOS consumes very little electrical energy at its voltage transition stage there is little energy loss under normal conditions. Furthermore, the impedance of a liquid crystal device is so high and its electric consumption so low that it forms a most suitable type of device for displaying time in a wrist watch. As will be obvious, six such devices as shown in Figure 1 will enable the time to be displayed, numerically in figures, in hours, minutes and seconds.

The driving circuit of Figure 2 is a D.C. driving circuit and has the serious disadvantage that, after the display device has been in use for some time the crystal material and the electrodes deteriorate as a result of hydrolysis and like effects produced by the D.C. This defect can be reduced or eliminated by substituting AC drive for D.C. drive but considerable problems then arise in achieving driving circuit structures of sufficiently small size and compact enough to be satisfactory for use in cases — such as that of a wrist watch — in which available space is extremely limited. A decoder arrangement employing Triac or like elements could be designed to provide AC drive to a liquid crystal display device, but Triac and like elements do not lend themselves to ready incorporation in integrated circuit structures, and a driving circuit employing such elements would be most difficult if not impossible to be made small enough for use for driving the numeric indicator of an electric wrist watch.

The present invention seeks to overcome these difficulties.

According to this invention, liquid crystal display apparatus comprises in combination at least one liquid crystal display device and AC drive means for said device, said drive means comprising integrated circuits consisting of complementary field effect transistors.

Said device may comprise a plurality of selectively energisable electrodes and be driven under the control of an integrated circuit decoder through AC driving circuits consisting of complementary field effect transistors and providing AC drive to said devices. The electrodes of said device are fed with AC through integrated circuit C-MOS selecting gates which form part of the aforesaid AC driving circuits and which are arranged, under the control of the decoded signals, to apply AC potential in one phase to the selected electrode or electrodes and in the opposite phase to a counter electrode which is common to the other electrodes of the device.

When applied to electronic timepieces the invention provides a timepiece having numeric display means consisting of a plurality of numeric liquid crystal display devices each of which has a plurality of selectably energisable electrodes and a counter electrode common thereto, said devices being arranged to display time in figures under the control of time measuring apparatus in the timepiece and being AC driven by drive means comprising integrated output circuits consisting of complementary field effect transistors.

Figure 3*a* shows diagrammatically the circuits of one embodiment of this invention. In this figure the IN (left hand) terminals *a'* to *g* are assumed to receive DC signals from an integrated circuit BCD decoder and AC drive signals are taken from the OUT terminals *a''* to *g''* to the elements of a display device (not shown) as in Figure 1. Between each IN terminal and the corresponding OUT terminal is a circuit comprising an inverter I_{IN} two pairs T_1 T_2 of complementary field effect transistors. An alternating voltage input, shown in line AC of Figure 3*b* as a square wave, is applied at terminal AC. I_n and I_2 are inverters and it will be seen that the alternating voltage at AC is applied after inversion, to the common counter electrode P and to a line connected to the junction points of the pairs of complementary field effect transistors in Figure 3*a*. The result is shown graphically in Figure 3*b* in which line AC is the alternating input at AC; line P''' is the alternating wave (inverted) on the electrode P and lines *a'''* to *g'''* represent outputs at the OUT terminals *a''* to *g''* respectively in Figure 3*a*. As will be seen during positive half waves on the AC line the transistors T_1 are turned "on" and the transistors T_2 are turned "off", their states reversing during negative half waves on the AC line. Figure 3*b* typifies the phase changes which occur, the portion marked 0 showing the output wave forms for displaying the numeral 0 (AC potential at *a''*, *b''*, *c''*, *d''*, *e''* and *f''* in phase opposition to AC potential on electrode P), and the portion marked 1 showing the output wave

forms for displaying the numeral 1 (AC potential at b'' and c'' in phase opposition to that on electrode P).

Figure 4 shows in manner similar to Figure 3*a* another embodiment of the invention. Like references are used for like parts in Figures 3*a* and 4 so little further description is necessary. Between each of the IN terminals a' to g' and the corresponding OUT terminal is an inverter I_{IN}, a pair of AND gates A_1 and A_2 and an OR gate A_3. These gates are of integrated circuit type employing C-MOS transistors. The action is much as in Figure 3*a*. In positive half waves of the AC on the AC line, the gates A_1 conduct and the gates A_2 block. On negative half waves the opposite happens.

Figure 5 is a simplified block diagram of an electronic wrist watch employing the present invention. Block TS represents a time standard oscillator such as one incorporating a quartz crystal or a mechanical vibrator the output from which is fed to a time counter TC in the form of a C-MOS structure. This counter produces second signals, minute signals and hour signals in manner known per se and requiring no description here. Block D represents a decoder and associated output circuits which are as already described with reference to Figure 3 or with reference to Figure 4 and to which AC voltage is supplied. The liquid crystal numeric time display system, is here shown as consisting of four devices for displaying hours and minutes.

As will now be seen, because the display devices are driven with alternating voltage, deterioration of the said liquid crystal displaying devices due to hydrolysis and like effects is avoided and the useful life of the said devices is very substantially increased. This advantage is obtained, in accordance with the invention by the use of circuitry in the form of integrated circuits employing C-MOS. Very small size and low power consumption are thus achieved so that an arrangement in accordance with this invention is very advantageous practically for watches and clocks and even for wrist watches, despite their small available internal space. Because the display elements are AC driven, the invention can be satisfactorily employed for clocks and watches with continuous display of the time by liquid crystal display devices. It is hardly practicable to provide continuous display of the time (as distinct from display of the time, when required, by operating a switch switching in the drives to the devices) by liquid crystal display devices driven, in known manner (typified by Figures 2*a* and 2*b*) by D.C. because of the deterioration which such driving causes in the display devices.

WHAT WE CLAIM IS:—

1. Liquid crystal display apparatus comprising, in combination at least one liquid crystal display device and AC drive means for said device, said drive means comprising integrated circuits consisting of complementary field effect transistors.

2. Apparatus as claimed in claim 1 wherein said device comprises a plurality of selcctably energisable electrodes, and is driven under the control of an integrated circuit decoder through AC driving circuits consisting of complementary field effect transistors and providing AC drive to said devices.

3. Apparatus as claimed in claim 2 wherein the electrodes of said device are fed with AC through integrated circuit C-MOS selecting gates which form part of said AC driving circuits and which are arranged, under the control of the decoded signals, to apply AC potential in one phase to the selected electrode or electrodes and in the opposite phase to a counter electrode which is common to the other electrodes of the device.

4. A timepiece including apparatus in accordance with any of the preceding claims and comprising a plurality of numeric liquid crystal display devices each of which has a plurality of selectably energisable electrodes and a counter electrode common thereto, said devices being arranged to display time in figures under the control of time measuring apparatus in the timepiece.

5. Display apparatus comprising at least one liquid crystal display device having a plurality of electrode elements and a common counter electrode and AC driving means for said apparatus substantially as herein described with reference to Figures 3*a* and 3*b* of the accompanying drawings.

6. Display apparatus comprising at least one liquid crystal display device having a plurality of electrode elements and a common counter electrode and AC driving means for said apparatus substantially as herein described with reference to Figure 4 of the accompanying drawings.

7. Electronic timepieces having time displaying apparatus in accordance with claim 5 or claim 6.

8. Electronic timepieces substantially as herein described with reference to the accompanying Figure 5.

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forms for displaying the numeral 1 (AC potential at b'' and c'' in phase opposition to that on electrode P).

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Figure 5 is a simplified block diagram of an electronic wrist watch employing the present invention. Block TS represents a time standard oscillator such as one incorporating a quartz crystal or a mechanical vibrator the output from which is fed to a time counter TC in the form of a C-MOS structure. This counter produces second signals, minute signals and hour signals in manner known per se and requiring no description here. Block D represents a decoder and associated output circuits which are as already described with reference to Figure 3 or with reference to Figure 4 and to which AC voltage is supplied. The liquid crystal numeric time display system, is here shown as consisting of four devices for displaying hours and minutes.

As will now be seen, because the display devices are driven with alternating voltage, deterioration of the said liquid crystal displaying devices due to hydrolysis and like effects is avoided and the useful life of the said devices is very substantially increased. This advantage is obtained, in accordance with the invention by the use of circuitry in the form of integrated circuits employing C-MOS. Very small size and low power consumption are thus achieved so that an arrangement in accordance with this invention is very advantageous practically for watches and clocks and even for wrist watches, despite their small available internal space. Because the display elements are AC driven, the invention can be satisfactorily employed for clocks and watches with continuous display of the time by liquid crystal display devices. It is hardly practicable to provide continuous display of the time (as distinct from display of the time, when required, by operating a switch switching in the drives to the devices) by liquid crystal display devices driven, in known manner (typified by Figures 2*a* and 2*b*) by D.C. because of the deterioration which such driving causes in the display devices.

WHAT WE CLAIM IS:—

1. Liquid crystal display apparatus comprising, in combination at least one liquid crystal display device and AC drive means for said device, said drive means comprising integrated circuits consisting of complementary field effect transistors.

2. Apparatus as claimed in claim 1 wherein said device comprises a plurality of selectably energisable electrodes, and is driven under the control of an integrated circuit decoder through AC driving circuits consisting of complementary field effect transistors and providing AC drive to said devices.

3. Apparatus as claimed in claim 2 wherein the electrodes of said device are fed with AC through integrated circuit C-MOS selecting gates which form part of said AC driving circuits and which are arranged, under the control of the decoded signals, to apply AC potential in one phase to the selected electrode or electrodes and in the opposite phase to a counter electrode which is common to the other electrodes of the device.

4. A timepiece including apparatus in accordance with any of the preceding claims and comprising a plurality of numeric liquid crystal display devices each of which has a plurality of selectably energisable electrodes and a counter electrode common thereto, said devices being arranged to display time in figures under the control of time measuring apparatus in the timepiece.

5. Display apparatus comprising at least one liquid crystal display device having a plurality of electrode elements and a common counter electrode and AC driving means for said apparatus substantially as herein described with reference to Figures 3*a* and 3*b* of the accompanying drawings.

6. Display apparatus comprising at least one liquid crystal display device having a plurality of electrode elements and a common counter electrode and AC driving means for said apparatus substantially as herein described with reference to Figure 4 of the accompanying drawings.

7. Electronic timepieces having time displaying apparatus in accordance with claim 5 or claim 6.

8. Electronic timepieces substantially as herein described with reference to the accompanying Figure 5.

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