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(54) LIQUID CRYSTAL PROTECTION CIRCUIT

(71) We, RCA CORPORATION, a corporation organized under the laws of the State of Delaware, United States of America, of 30 Rockefeller Plaza, City and State of New York, 10020, United States of America, 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:—

Liquid crystal displays such as numeric indicators e.g. in electronic timepieces are often driven by integrated circuits. Such circuits may be battery operated and they apply unipolarity alternating voltages to the backplate and segments of the display. The backplate may receive, for example, a relatively low frequency unipolarity voltage of one phase and the segments may receive a signal of the same frequency which is either in-phase with or out-of-phase with the backplate voltage. It sometimes occurs that the oscillator for the circuit, that is, the generator of the low-frequency unipolarity voltage, fails while the battery serving as the operating voltage source for the liquid crystal driver circuits still is producing a substantial direct voltage level. Under these circumstances, that is, the oscillator inoperative and the transistor driver operating voltage still present, direct voltages may develop across certain segments of the display and the backplate of the display and these static voltages may seriously affect the life of the liquid crystal.

In the present invention, the condition of the oscillator is sensed and when its oscillations cease, the direct voltage for the liquid crystal driver transistors is interrupted. A preferred embodiment includes a charge storage means connected through the conduction path of a transistor to a terminal for the operating voltage. The control electrode of the transistor receives the oscillations. When these oscillations are present, the charge storage means is charged, once each period of the oscillations, and this charge storage means operates as the operating voltage

source. When the oscillations cease, the transistor is turned off and the charge of the charge storage means dissipates within a short period of time, thereby removing the source of operating voltage.

The invention is discussed in detail below and is illustrated in the drawing of which:

FIGURE 1 is a block circuit diagram of a prior art liquid crystal display and driver circuit;

FIGURE 2 is a block and schematic circuit diagram illustrating the improvement of the present invention; and

FIGURE 3 is a more detailed showing of a portion of the system of FIGURE 2.

The problem dealt with in the present application is illustrated in the prior art system of FIGURE 1. Oscillator 10, which may be operated from a -5 volt operating voltage source V_{SS} , supplies a unipolarity alternating voltage to the integrated circuit 12. This voltage may, for example, be at a frequency of 30 Hz and may have an amplitude of 5 volts, that is, it may vary between limits of 0 and -5 volts.

This integrated circuit 12 may be the commercially available CD4055AE, such as described in the RCA Solid State Data Book COS/MOS Digital Integrated Circuits for 1973. This circuit includes a level shifter receptive of the oscillations produced by oscillator 10 and of a binary coded decimal (BCD) input. The four BCD voltages are applied to pins 2, 3, 4, 5 and the oscillations to pin 6. The level shifter within the circuit 12 is connected to a BCD-to-seven-segment decoder and the decoder is connected to the display driver transistors which receive V_{EE} voltage from pin 7. Pins 9-15 of the integrated circuit 12 connect to the seven segments of number indicator 14. Pin 1 of the circuit connects to the backplate of the numeric indicator.

In the operation of the circuit of FIGURE 1, the level shifter within circuit 12 applies amplified oscillations to pin 1. These oscillations may have an amplitude of 15 volts, that is, the alternating voltage may swing

between limits of 0 and -15 volts. This signal is applied to the backplate. The level shifter also drives the BCD-to-seven-segment decoder in response to the four control voltages received at pins 2-5, and the decoder applies its output to the display driver within circuit 12. The latter, in response to these decoder outputs and to the amplified oscillations from the level shifter, applies to the respective segments a 15 volt amplitude (0 to -15 volt swing) 30 Hz unipolarity signal which is either in-phase with or out-of-phase with the backplate voltage. For example, when it is desired that the indicator display the numeral 3, then the display drivers apply a 30 Hz voltage in-phase with the backplate voltage to the segments e and f and a 30 Hz voltage which is 180° out-of-phase with the backplate voltage to the remaining segments a, b, c, d and g. The result of this operation is the simulation of a 30 volt bipolar alternating voltage across the liquid crystal at segments a, b, c, d and g and zero volts appears across the liquid crystal at segments e and f. The 30 volt excitation causes the liquid crystal, in the event that it is of dynamic scattering type, to become excited and to scatter light. (Other types of liquid crystals, such as that which in its excited state is dark and its unexcited state is clear, may be used instead.)

It sometimes occurs in the system of FIGURE 1 that the V_{SS} supply voltage decreases sufficiently that the oscillator 10 goes off. This may occur while the V_{EE} supply voltage is still at some substantial value such as -10 or -11 or some higher (or lower) voltage. When the oscillator goes off, the backplate voltage may go to ground. The driver transistors no longer receive oscillations either. However, the states they assume, whether conducting or not, will depend upon the values of the direct control voltages they receive from the BCD decoder. Some of these transistors will be in a conducting state and rather than applying a unipolarity alternating voltage to the respective segments they drive, will instead apply a direct voltage almost equal to V_{EE} . Thus, when the oscillator stops and the backplate goes to ground, while some of the segments also will go to ground, others will "hang" at almost V_{EE} in view of the conducting path via a driver transistor between pin 7 (to which the V_{EE} voltage is applied) and these segments. This direct voltage component, if not removed, may damage or destroy the liquid crystal.

The circuit of FIGURE 2 illustrates the solution of a preferred embodiment of the present invention to the problem above. The circuit includes a transistor 16 connected at its collector 17 to the V_{EE} supply voltage terminal and at its emitter 19 to pin 7 of the integrated circuit. Thus, as contrasted to

the FIGURE 1 circuit, the emitter-to-collector path of a transistor is now located between the operating voltage terminal and pin 7. The base 21 of transistor 16 is connected through capacitor C_1 to the oscillator 10 output terminal. The base 21 also connects through resistor 18 to the emitter 19 of the transistor. The capacitor C_2 is connected between emitter 19 and pin 16 of the integrated circuit. Pin 16 is the one at V_{DD} , that is, at ground potential.

In the operation of the circuit of FIGURE 2, when the oscillator is on, the oscillations are applied through capacitor C_1 to the base 21. Each time the oscillator voltage goes to -5 volts, transistor 16 goes on and current flows from ground through capacitor C_2 and the emitter-to-collector path of transistor 16 to the V_{EE} terminal. Within a very short period of time, capacitor C_2 becomes charged almost to -15 volts, applying this -15 volts to pin 7 of the integrated circuit.

When V_{SS} drops sufficiently so that the oscillator stops, the output terminal of the oscillator assumes a direct voltage level. It may be assumed that this direct voltage level is ground for purposes of the present explanation. This direct voltage cannot pass through capacitor C_1 . Resistor 18 places the base electrode 21 at the same potential as the emitter electrode so that transistor 16 goes off. The charge present on capacitor C_2 now leaks off through certain of the transistors in the integrated circuit 12, and within a short period of time (usually within 10 seconds or so) the voltage at pin 7 reduces to ground level. This removes any direct current components from across the liquid crystal.

The drive circuit for one segment of the display (which also operates as the discharge circuit for the capacitor) is shown in greater detail in FIGURE 3. It includes two complementary symmetry, metal-oxide-semiconductor (COS/MOS) inverter drivers P_1 , N_1 and P_2 , N_2 , respectively. The N type transistors N_1 and N_2 connect at their source electrodes to one terminal of capacitor C_2 and the P type transistors P_1 and P_2 connect at their source electrode to V_{DD} (ground). Each inverter receives at its common gate electrode connection (its input terminal) a level shifted unipolarity 30 Hz signal having an amplitude V_{EE} . The common drain connection of inverter P_1 , N_1 connects to one of the segments and the common drain connection of inverter P_2 , N_2 connects to the backplate of the liquid crystal numeric indicator.

The switch 51, in practice, comprises MOS transmission gates. In the position of the switch shown, it applies the wave 50 to input terminal 52, this wave being complementary to the wave 54 applied to input terminal 56. Thus the segment shown is a "selected" segment in the sense that in

normal operation it will receive a voltage 180° out of phase with the voltage applied to the backplate, and an alternating voltage of amplitude substantially equal to $2 V_{EE}$ will appear across and excite the liquid crystal.

In the operation of the circuit of Figure 2, the bipolar transistor 16 is driven by the 30 Hz signal of amplitude V_{SS} as already described. Assume that V_{SS} reduces sufficiently so that the oscillator goes off and the driving voltage for transistor 16 stops at ground level. The absence of the alternating voltage 58 causes transistor 16 to go off; however, the voltage across capacitor C_2 is at that moment close to V_{EE} . Assume also that when the oscillator goes off, the wave 50 applied through switch 51 to input terminal of inverter P_1 , N_1 is at ground level and the wave 54 applied to input terminal 56 of inverter P_2 , N is at V_{EE} level. (It is of course understood that the level shifted waves 50 and 54 are derived within the chip 12 from the wave 58 produced by the oscillator so that when the wave 58 stops at a given level, waves 50 and 54 also stop at given static levels.)

As the voltage applied to terminal 50 is at ground, transistor P_1 is cut off and transistor N_1 is turned on. As wave 54 is at V_{EE} , transistor P_2 is turned on and transistor N_2 is turned off. Thus there is low impedance conduction path from capacitor C_2 through transistor N_1 to the segment shown in FIGURE 3. Similarly, there is a low impedance conduction path from ground through transistor P_2 to the backplate shown in FIGURE 3. The liquid crystal itself is of relatively high impedance; however, within a reasonable period of time, the capacitor C_2 discharges through transistor N_1 , the liquid crystal and transistor P_2 to ground. The discharge time is a matter of 10 seconds or so and will depend largely upon the value of capacitance C_2 and the resistance exhibited by the liquid crystal.

In the example given above by way of illustration, the oscillator stopped oscillating at a time such that wave 58 was at a level of zero volts. It is equally possible for the oscillator to stop oscillating when the wave 58 is at the V_{SS} level. In this case, in the example illustrated, wave 50 would be at the V_{EE} level and wave 54 at the zero level. This would mean that the discharge path of capacitor C_2 would be through transistor N_2 , the liquid crystal, and transistor P_1 to ground. The capacitor C_2 discharge time is approximately the same as for the first case, namely 10 seconds or so.

When the BCD input voltages are such that switch 51 applies wave 50 to terminal 52, the segment is "non-selected". In normal operation, the non-selected segment re-

ceives a voltage which is in phase with the backplate voltage so that zero volts develop across the liquid crystal. When the oscillator fails, both input terminals 52 and 56 are at V_{EE} so that transistors P_1 and P_2 are both on. This places both the non-selected segment and backplate at ground and no voltage is present across the portion of the liquid crystal beneath the non-selected segment. The capacitor C_2 , of course, in due course, discharges through other of the inverter drive circuits within the chip and through the liquid crystal, via selected segments, as already described.

It is also possible in the case of a non-selected segment, for waves 50 and 54 both to stop at ground level. In this case transistors N_1 and N_2 would be on at the same time so that the non-selected segment and backplate would be at V_{EE} . Here too there would be no problem because zero volts would be present across the liquid crystal. Again this condition is just a momentary condition because within 10 seconds or so the capacitor C_2 discharges through other of the circuits within chip 12 such as shown in FIGURE 3 and the non-selected segment and backplate both go to ground level.

In a practical circuit such as described, in most cases V_{SS} and V_{EE} are separate batteries. The electrical capacities of these batteries are picked to have equal lives but it is rare that both batteries fail at the same moment. If the V_{EE} battery fails first, no permanent harm can result. However, if the V_{SS} battery fails and the display oscillations (58 of FIGURE 3) stop, damage to the liquid crystal as described above is almost certain. In this practical circuit, the oscillator generally stops when the V_{SS} voltage drops somewhat below -2 volts, it being quite abnormal for the oscillator to continue working much below -1.5 volts.

By a unipolarity alternating voltage is meant one which alternates between, say, zero and a positive level or zero and a negative level, rather than alternating between positive and negative levels as does a bipolar alternating voltage.

WHAT WE CLAIM IS:—

1. A combination including a liquid crystal display element having at least two electrodes, an oscillator producing a unipolarity alternating output voltage, a drive circuit to be powered by a direct current operating voltage and responsive to the unipolarity alternating output voltage of said oscillator for applying a bipolar alternating voltage between said two electrodes for operating said liquid crystal display element, sensing means for sensing the presence of said unipolarity alternating output voltage, and means responsive to said sensing means for removing

normal operation it will receive a voltage 180° out of phase with the voltage applied to the backplate, and an alternating voltage of amplitude substantially equal to $2 V_{EE}$ will appear across and excite the liquid crystal.

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said direct current operating voltage from said drive circuit when said unipolarity alternating output voltage is no longer effectively present.

- 5 2. A combination as claimed in Claim 1 wherein said means responsive to said sensing means comprises a switch.

3. A combination as claimed in Claim 1 wherein said sensing means comprises an alternating current coupling element and said means responsive to said sensing means comprises a switch recurrently switchable by an applied alternating voltage, said alternating current element serving to couple said unipolarity alternating voltage to said switch and said switch remaining open upon the termination of said voltage.

4. A combination as claimed in Claim 3, wherein said alternating current coupling element is a capacitor and said switch is a transistor having its control electrode connected to said capacitor, one of its main terminals connected to a terminal for a direct current operating voltage and the other of its main terminals connected to one plate of

a second capacitor, the other plate of which is connected to a point of reference potential.

5. A combination as claimed in Claim 1, wherein the direct current operating voltage for said drive circuit is provided by a capacitor which is maintained in a charged state in response to said unipolarity alternating voltage, and wherein said means responsive to said sensing means comprises a switch in circuit with said capacitor and which is alternately opened and closed in response to the presence of said unipolarity alternating voltage and which remains open in the absence of said unipolarity alternating voltage.

6. A liquid crystal display with associated circuitry substantially as hereinbefore described with reference to Figure 2 or Figure 3 of the accompanying drawing.

T. I. M. SMITH,
Chartered Patent Agent,
50, Curzon Street,
London. W1Y 8EU
Agent for the Applicants.

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