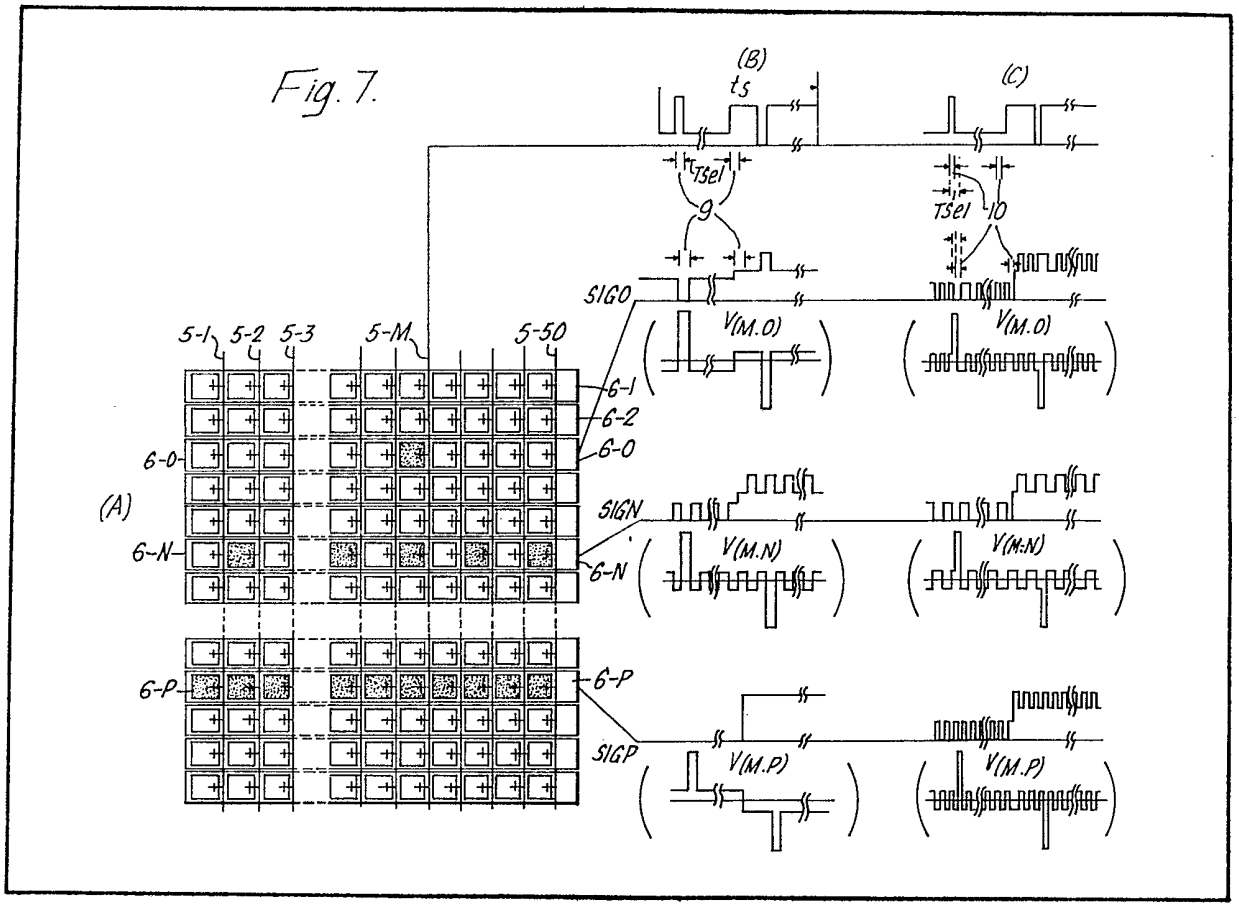
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(54) **Improvements in liquid crystal displays and methods of driving**

(57) In a liquid crystal matrix display panel including a varistor or other non-linear device in series with each element, multiplex driving is assisted by dividing each scanning period (t_{se1}) in a frame time (t_s) (with voltage swings reversed in second half to avoid d.c.) into two 'fine' scanning periods, in one of which the scanning voltage on the scanned line (column, e.g. S—M see Fig. 7(a)) takes the selection value, and in the other it takes the non-select value (see Fig. 7(c)): the signal electrodes (rows 6—O, 6—N, 6—P, Fig. 7(a)) selected to display in column S—M receive in the first 'line' scanning period of that column their selection voltage and in the second their non-select voltage, while electrodes (rows) not selected to display receive non-select voltage in the first and select in the second. The voltages V across elements M—O, M—N, M—P charge the liquid crystal and varistor capacitances, holding charge throughout the following frame. The stabilizing of the average voltage on unselected elements, as compared with Fig. 7(b) prior art, reduces interference from other elements on the same row, allowing a higher degree of multiplexing and the display of grey scale.



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The drawings originally filed were informal and the print here reproduced is taken from a later filed formal copy.

Fig. 1.

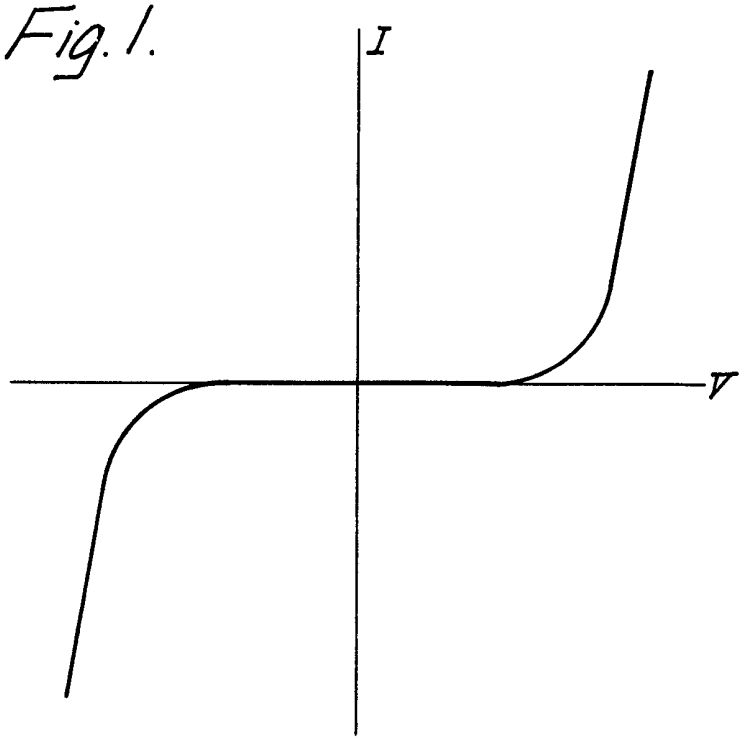
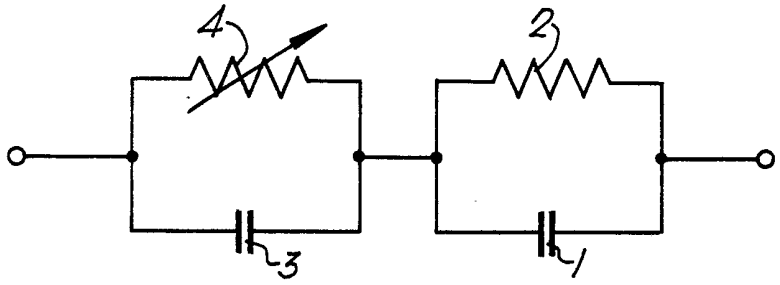


Fig. 2.



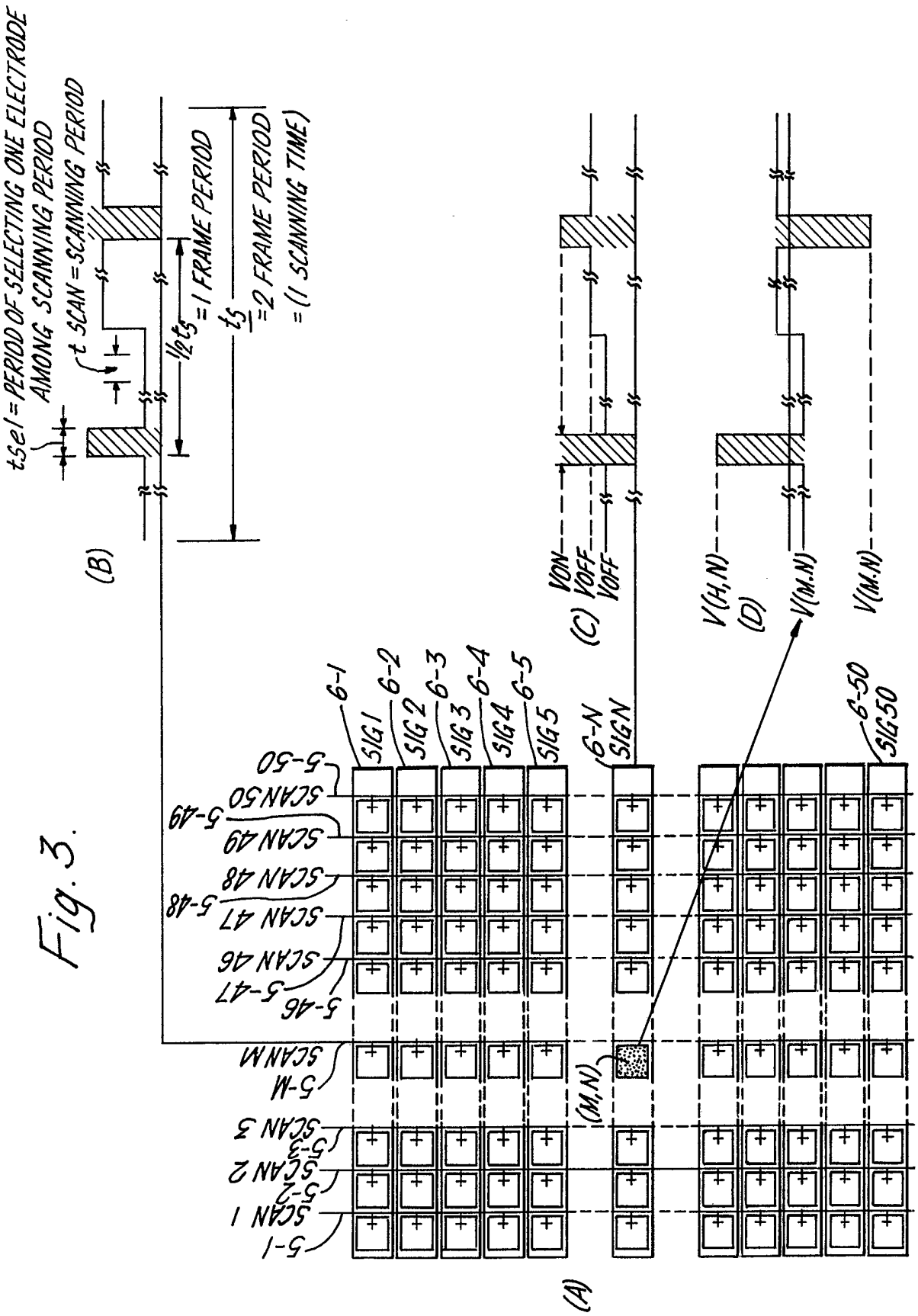

tsel = PERIOD OF SELECTING ONE ELECTRODE AMONG SCANNING PERIOD
t SCAN = SCANNING PERIOD
1/2 ts = 1 FRAME PERIOD
ts = 2 FRAME PERIOD = (1 SCANNING TIME)
(B)
VON
VOFF
VOFF
(C)
V(H,N)
(D)
V(M,N)
V(M,N)
6-1
SIG1
6-2
SIG2
6-3
SIG3
6-4
SIG4
6-5
SIG5
6-N
SIGN
6-50
SIG50
5-1
SCAN 1
5-2
SCAN 2
5-3
SCAN 3
5-M
SCAN M
5-46
SCAN 46
5-47
SCAN 47
5-48
SCAN 48
5-49
SCAN 49
5-50
SCAN 50
(M,N)
(A)

Fig. 3.

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Fig. 4.

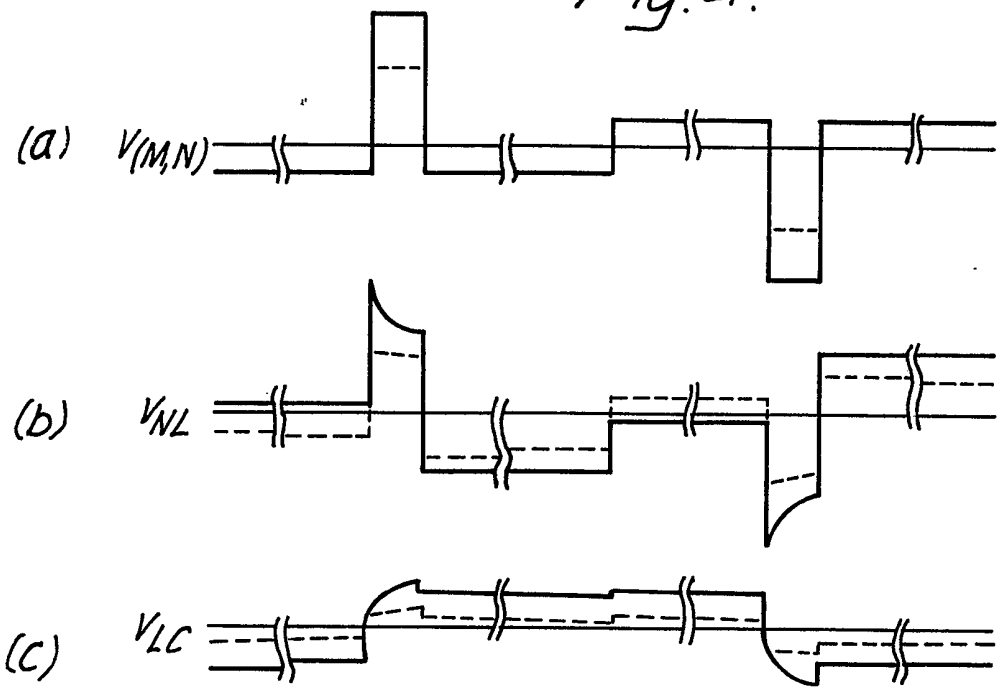


Fig. 5.

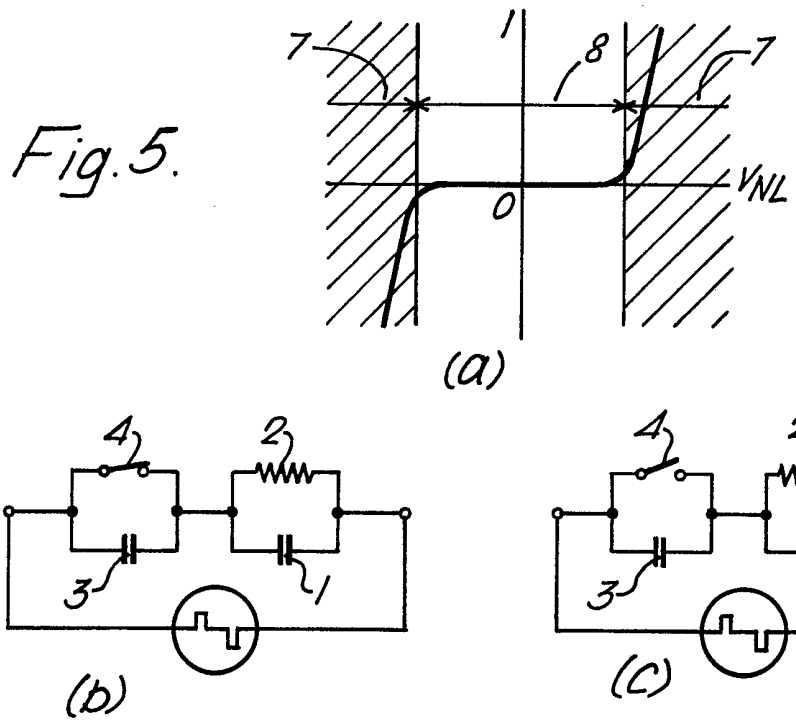
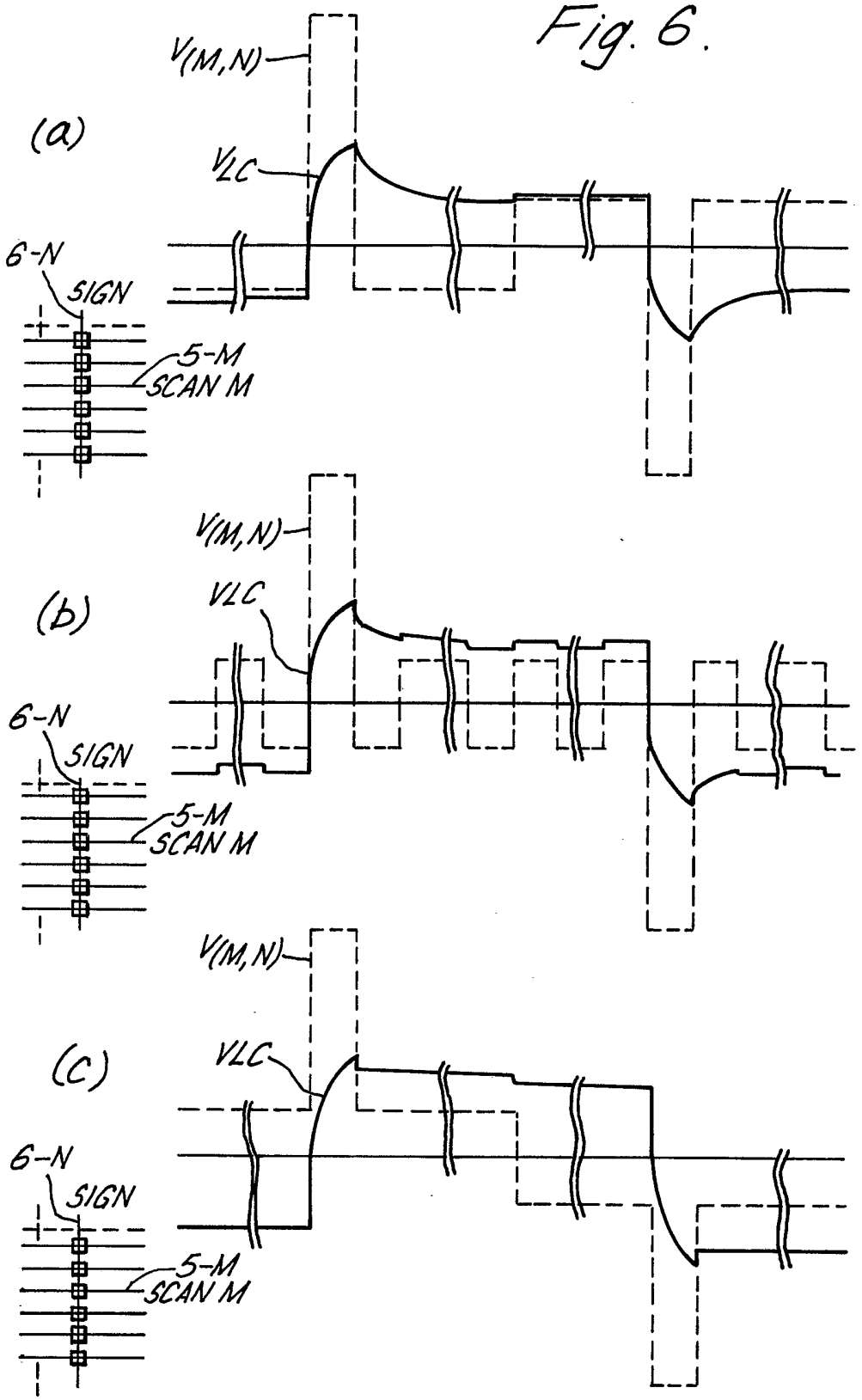


Fig. 6.


(a)
V(M,N)
VLC
6-N
SIGN
5-M
SCAN M
(b)
V(M,N)
VLC
6-N
SIGN
5-M
SCAN M
(c)
V(M,N)
VLC
6-N
SIGN
5-M
SCAN M

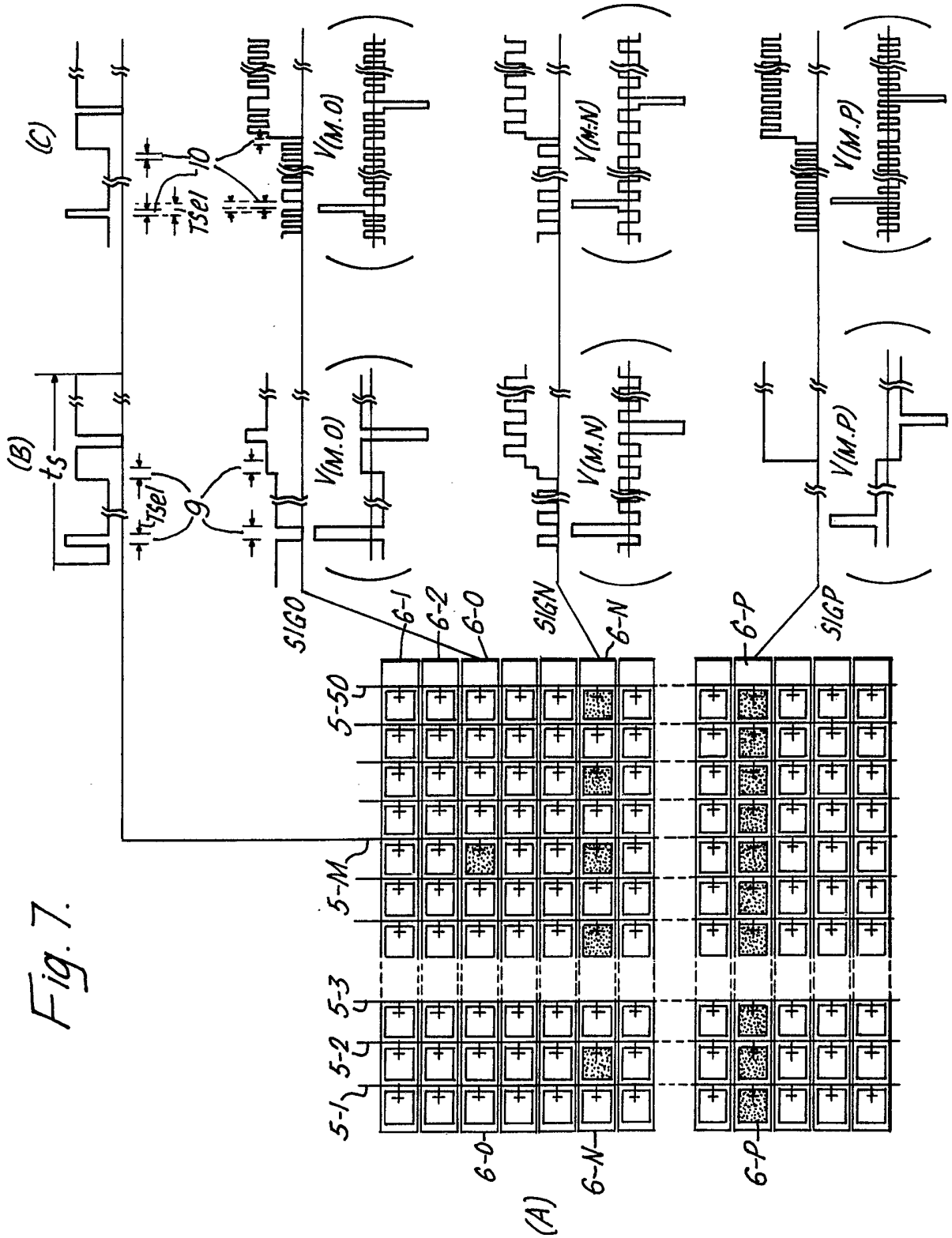
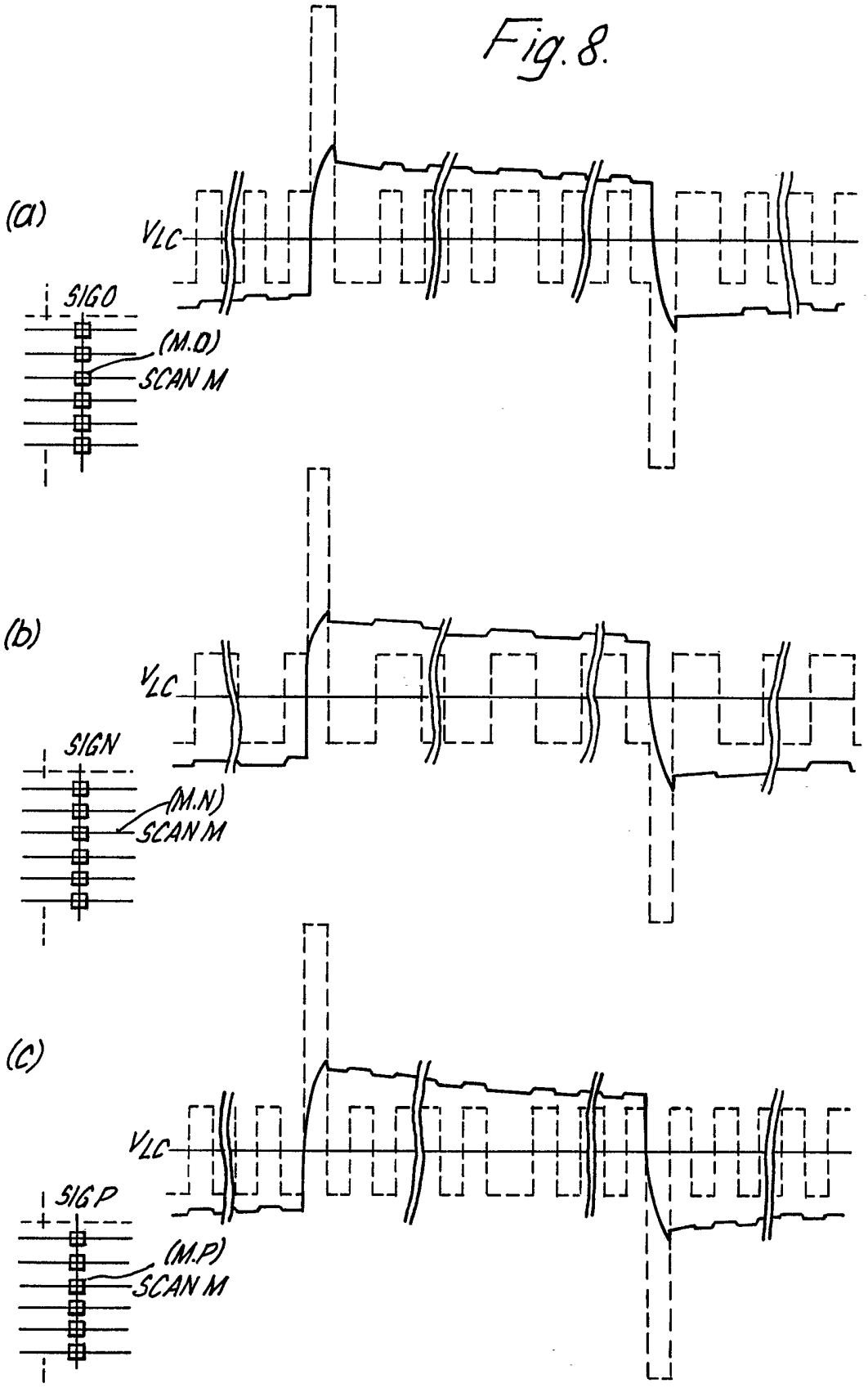

(B)
ts
tTsel
Tsel
9
(C)
Tsel
10
V(M.0)
V(M.0)
V(M.N)
V(M.N)
V(M.P)
V(M.P)
SIG0
SIGN
SIGP
6-1
6-2
6-0
6-N
6-P
5-50
5-M
5-3
5-2
5-1
6-0
6-N
6-P
(A)

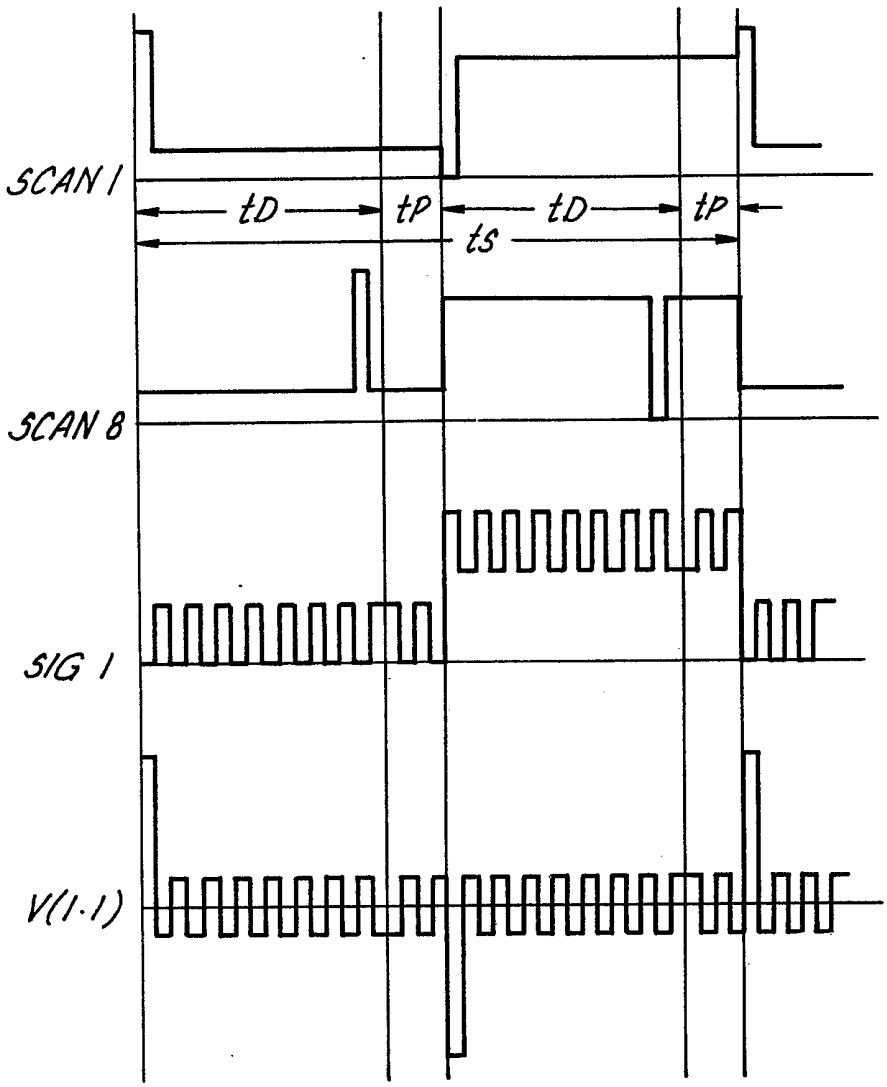
Fig. 7.

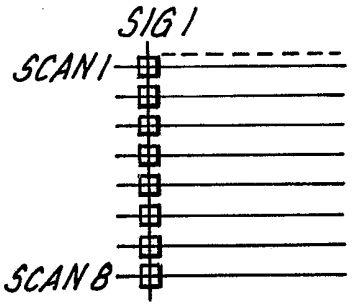
Fig. 8.



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Fig. 9.





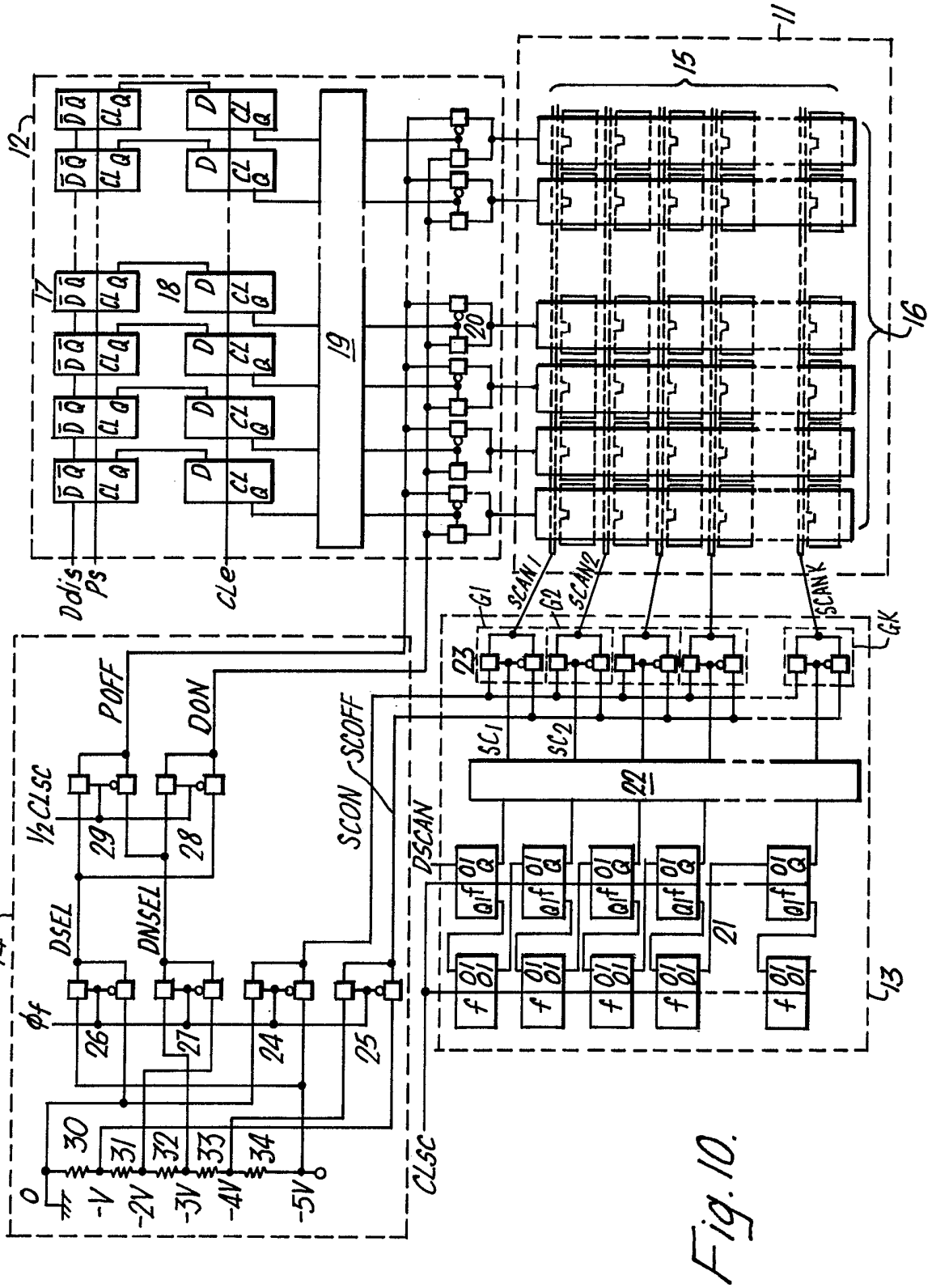

11
12
13
14
15
16
17
18
19
20
21
22
23
Ddis
Ps
Cle
SCAN1
SCAN2
SCANY
G1
G2
GK
SC1
SC2
POFF
DON
SCOFF
SCON
DSCAN
½CLsc
DSEL
DNSEL
Φf
CLsc
0
-1V
-2V
-3V
-4V
-5V
24
25
26
27
28
29
30
31
32
33
34

Fig. 10.

Fig. 11.

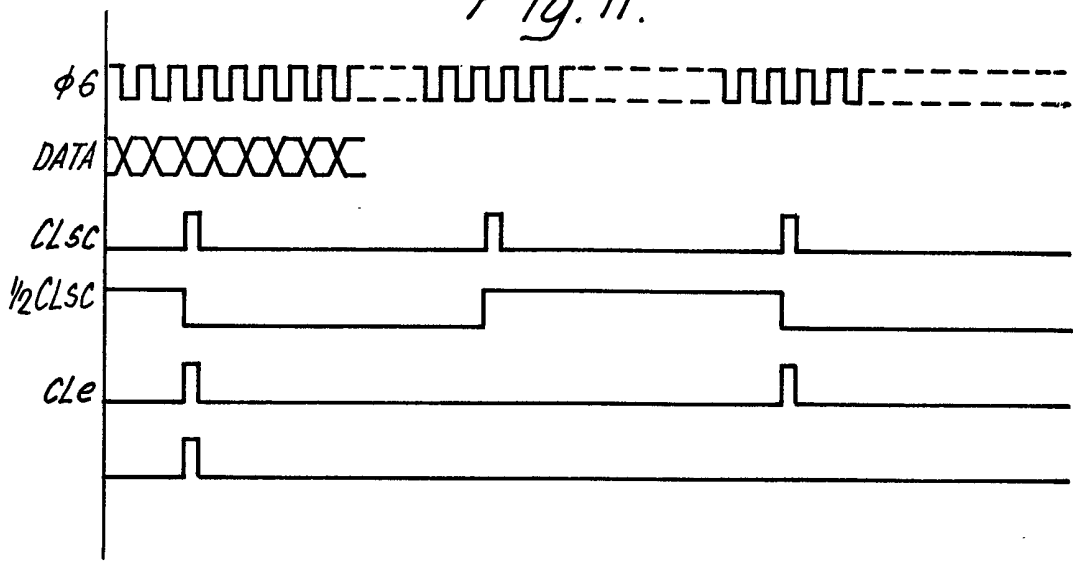
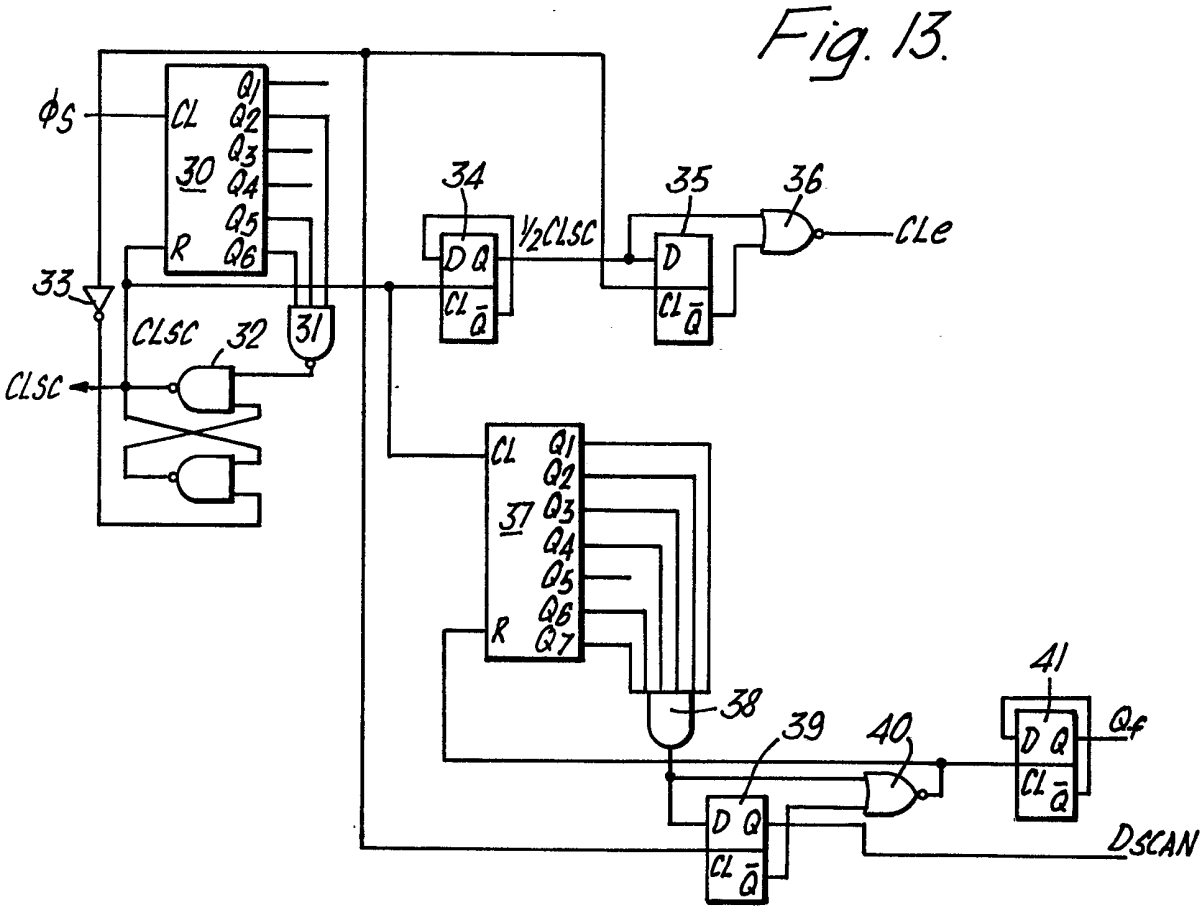
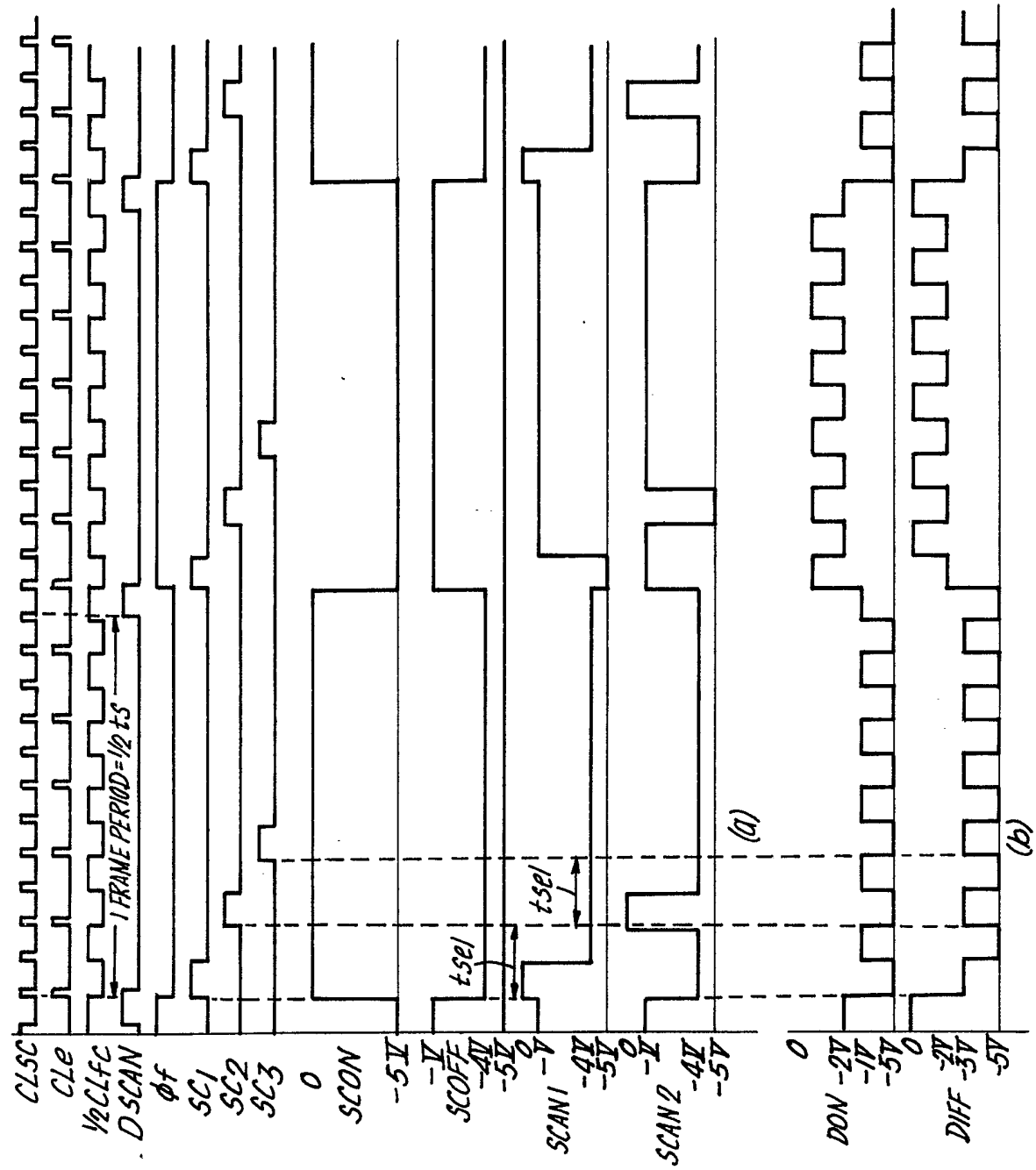

φ6
DATA
CLSC
½CLSC
CLe

Fig. 13.


φS
CL
Q1
Q2
Q3
Q4
Q5
Q6
R
30
33
CLSC
32
31
34
35
36
½CLSC
CLe
D
Q
37
Q7
38
39
40
41
Qf
DSCAN

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Fig. 12.



SPECIFICATION

Improvements in or relating to liquid crystal electro-optical apparatus and to methods of driving the same

This invention relates to liquid crystal electro-optical devices apparatus and methods of driving the same.

The use of liquid crystal for display purposes in electro-optical devices has expanded greatly in recent years and liquid crystal material is now used in a wide variety of devices examples of which are light valves, the displays of electronic calculators and the time displays of electronic timepieces, notably wrist watches. It is now under consideration to use liquid crystal displays in small-sized personal computers and similar devices. However, the dynamic system most commonly employed at present in a conventional liquid crystal display arrangement has a very limited driving duty ratio, the limiting ratio being in practice 1/30 or thereabouts. This limitation makes it difficult if not impossible for such a conventional arrangement to display large amounts of information often required in devices such as computers. A number of proposals have been made to overcome this difficulty and improve the driving duty ratio of the dynamic system, the following having been suggested:—

(1) Use of non-linear devices in addressing the liquid crystal electro-optical device to be driven

Examples of non-linear devices which could be used in addressing are:—

(a) varistors
(b) metal-insulator-metal (MIM) devices
(c) diodes
(d) discharge tubes

(2) Use of an active switching addressing system

Examples of such addressing are:—

(a) thin film transistor addressing
(b) MOS transistor addressing
(c) triac addressing

(3) Use of a light-heat writing system for addressing

Examples of such addressing are by using:—

(a) laser-heat writing
(b) light-conductor writing

(4) Use of a two-frequency addressing system

Known proposals in which non-linearity is restored to—e.g. in which one or other of the above expedients is resorted to—provide substantial improvement as regards data handling capacity when compared with the more conventional and widely used liquid crystal device display arrangements which do not incorporate non-linear devices in the driving circuits but they present serious defects, notably as regards quality of the display, which arise from causes which are by no means obvious.

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

Figure 1 shows the voltage current (V/I) characteristic of a typical non-linear device such as MIM device,

Figure 2 is a simplified equivalent circuit diagram of a non-linearly driven liquid crystal display device,

Figure 3 represents diagrammatically a liquid crystal display device with a matrix of display picture elements and includes waveforms used to drive the said device by the conventional generalized AC amplitude selective multiplexing method,

Figures 4, 5 and 6 are explanatory waveform diagrams relating to known proposals for achieving non-linear driving,

Figure 7 illustrates the method of the present invention and includes waveforms which provide comparison between the method of the present invention and the known methods,

Figures 8 and 9 are waveform diagrams relating to the operation of apparatus in accordance with this invention, Figure 8 showing voltage applied to the liquid crystal layer and Figure 9 showing driving waveforms.

Figure 10 shows diagrammatically one embodiment of this invention,

Figure 11 and Figures 12(a) and (b) are explanatory timing waveform diagrams relating to the embodiment of Figure 10, and

Figure 13 is a diagram of a controlling circuit which may be used in carrying out this invention.

Before coming to a description of the present invention, an explanation will first be given of the way in which in known arrangements of the non-linear type, the non-linear element, whether an active switching element or a passive element increases the display capacity of the electro-optical device but also has a serious disadvantageous effect on the quality of the display.

Figure 1 shows the non-linear voltage-current characteristic of a typical MIM device. In Figure 1 the abscissa V is voltage and the ordinate I is current. A similar non-linear characteristic is exhibited by the combination of a varistor and diode connected in series, with the diode connected in the reverse direction, the combination utilizing the avalanche break down voltage in the Pn junction. As will be seen later any of a variety of non-linear elements can be used as a switching element in carrying out this invention provided it has a non-linear characteristic wherein the resistance is high in the region of low voltage and is low in the region of high voltage as shown in Figure 1.

The equivalent circuit, shown in Figure 2, comprises the capacitance 1 of value CLC 1 and the resistance 2 of value RLC 2 of a picture element in a liquid crystal display device and the capacitance 3 of value CNL 3 and the varying resistance 4 of varying value RNL 4 of a non-linear device such as an MIM device. The value of RNL 4 is low when the voltage applied to the non-

linear device is high, and is high when the voltage applied to said non-linear device is low.

Figure 3(A), (B), (C) and (D) shows what happens when a driving waveform of 1/50 duty ratio and with a 1/5 bias ratio is applied between the terminals of the equivalent circuit of Figure 2. Figure 3(A) shows diagrammatically a matrix of display picture elements consisting of scanning electrodes 5-1 to 5-50 and signal electrodes 6-1 to 6-50. Scanning signals SCAN1 and SCAN50 are respectively applied to the scanning electrodes 5-1 to 5-50. Display signals SIG1 to SIG50 are respectively applied to the signal electrodes 6-1 to 6-50. In this diagram the shaded display picture element (M,N) corresponding to a scanning electrode 5-M and a signal electrode 6-N is in the lighted state and the other display picture elements are in the non-lighted state. Figure 3(B) shows the waveform of the scanning signal in this case and Figure 3(C) shows the waveform of the display signal. In Figure 3(B), *ts* is a scanning period in which signals are applied to all the display picture elements and Tsel is a selected period of the scanning signal SCAN M by which the scanning electrode 5-M is selected. As shown in Figure 3(C), the signal electrode 6-N is ON, i.e. has a voltage VON in this selected period Tsel, and is OFF i.e. has a voltage V OFF at the other times indicated and the voltage V (M,N) applied to the display picture element (M,N) is given by

$$V(M,N)=SCAN\ M-SIG\ N$$

as shown in Figure 3(D).

Figure 4(a) shows by a solid line, the waveform V(M,N) of the applied voltage at the time the display picture element (M,N) is ON with a voltage VON; Figure 4(b) shows by a solid line the voltage waveform VNL across the non-linear device; and Figure 4(c) shows by a solid line the voltage waveform VLC applied to the liquid crystal layer. As will be seen from Figure 4:—

$$V(M.N)=VNL+VLC$$

The broken lines in Figures 4(a), (b) and (c) indicate the waveforms when the display picture element (M.N) is OFF with a voltage VOFF.

Figures 5(a), (b) and (c) diagrammatically indicate what happens upon activation of the non-linear device and the liquid crystal layer. Figure 5(a) indicates, in the same way as Figure 1, the applied voltage VNL—current I characteristic of the non-linear device. As will be seen from Figure 5(a) the resistance of the non-linear device is low in the regions 7 and is high in the region 8. Figure 5(b) illustrates the current flow situation in the case where the resistance RNL 4 of the non-linear device is low (almost zero), while Figure 5(c) similarly illustrates the current flow situation in the case where the resistance RNL4 of the non-linear device is high (almost infinity). As shown by Figure 5(b), when the non-linear device is in a region of low resistance almost all the driving voltage is applied to the liquid crystal layer so that said layer is charged. At this time the time constant τ is obtained from a consideration of the equivalent circuit of Figure 2 is given by:—

$$\tau=(CLC+CNL)\times\frac{RLC\times RNL}{RCL+RNL} \qquad (1)$$

As will be appreciated from this equation, if the resistance RNL of the non-linear device is nearly zero, a current (i) will flow transiently to charge the capacitance 1 of value CLC 1 (see Figure 2) and, at this time practically all the voltage is applied to liquid crystal layer.

Subsequently, when the display picture element M.N is in a non-selected period (voltage V(MN)) the non-linear device turns from the region of low resistance 7 into a region of high resistance 8, and its resistance changes accordingly from RLC to RNL, where RLC<<RNL, and the current (i), which transiently flows, flows through RLC. This is the situation in Figure 5(b). At this time the time constant τ is approximately given by

$$\tau=(CLC+CNL)\ RLC \qquad (2)$$

In general, the liquid crystal material utilized in a liquid crystal display panel of the field effect type exhibits a resistance RLC of very high value. Accordingly, it is possible in practice to make τ as long as the scanning time.

Referring to the wave forms indicated by the broken lines in Figures 4(a), (b) and (c), i.e. when the display picture element is in the non-lit condition, the value of the applied voltage VNL, even at its peak, is not enough to charge the liquid crystal layer and produce lighting of the element, and VLC remains at low level. Accordingly, the difference between the effective value of the lighting voltage level and the non-lighting voltage level in the liquid crystal layer is considerably greater, due to the employment of the non-linear device, than it is in the case of the more generalized AC amplitude selective multiplexing method of driving in which a non-linear device is not employed. Therefore the provision of the non-linear device as described above enables multiplex driving with many more scanning lines to be effected and the display capacity of the liquid crystal display thus to be substantially increased.

Nevertheless, a multiplexing driving system as so far described has the serious disadvantage that, the effected voltage applied to the liquid crystal layer varies due to the display signal in the nonselected period. This disadvantage and its effects will now be explained with the aid of Figures 6(a), (b) and (c).

Figure 6(a) illustrates the waveform of the voltage VLC which occurs at a time when only one display signal electrode column 5-M in a signal electrode row 6-N is lit. Figure 6(b) illustrates the waveform of the voltage VLC which

occurs at a time when every second line of display signal electrodes in a signal electrode row 6-N is lit. Figure 6(c) illustrates the waveform which occurs at a time when all the display signal electrodes in a signal electrode row 6-N are lit. The voltage V (M.N) applied to the display picture element (M.N) is represented by broken lines and the voltage VLC applied to the liquid crystal layer is represented by solid lines. It will be seen from a consideration of Figures 6(a), (b) and (c), that VLC is subject to and greatly varied in dependence upon whether or not other picture elements associated with the same signal electrode (SIG) are lit. A corresponding dependence exists in the case in which the considered display picture element (M.N) is not lit. To display a conventional binary digit, the minimum value (EON min) of the effective voltage of the lighting waveform must be larger than the saturation voltage (Vsat) of the liquid crystal and the maximum value (EOFF max) of the effective voltage of the non-lighting waveform must be smaller than the threshold voltage (Vth) of the liquid crystal. Accordingly it has been recognised that known non-linear driving systems are practically suitable only for the display of binary digits but not suitable for giving a so-called "grey scale" display. In addition, if the values of EON min and EOFF max have to be fixed to close tolerances, the requirements as regards quality of characteristic of the non-linear device are so onerous as to be very difficult to satisfy. Still further, there is a problem as regards the display itself, for the variation of the effective voltage is directly manifested in the display as a variation in contrast in the case in which the value of the saturation voltage is somewhat indefinite, for example, because of Guest-Host Effect.

The present invention seeks to avoid the above-mentioned serious disadvantage and to provide improved matrix type liquid crystal electro-optical apparatus and methods of driving the same which provide a large data handling capacity, a clear display of good quality and contrast, avoid undesirable variation of contrast in the display, avoid the need for close tolerances, are capable of giving a grey scale display and are relatively simple as regards the driving circuitry required. These objects are achieved by reduction of undesired variation of the effective voltage of the liquid crystal layer by making EONMIN and EONMAX approach a medium value, making the discharge of liquid crystal substantially constant at a time when the switching element is OFF by subdividing one scanning period into a plurality of selected levels and non-selected levels. If this is done, a non-linear device which is also an active switching device (such as a thin film transistor (TFT) or an MOS transistor) can be used in the driving system of a liquid crystal display device without introducing, to any substantial extent, the disadvantages of known non-linear driving systems.

According to this invention in one aspect there is provided an electro-optical matrix type liquid crystal display device and a nonlinear driving and addressing system therefor wherein the time during which selection of a picture element is effected is shortened and the average value of the driving voltage during non-selected periods is maintained substantially free of variation by dividing the scanning period as herein defined into at least two fine scanning periods as herein defined, the voltage applied during at least one fine scanning period in a scanning period being of one pre-determined level and that applied during other fine scanning periods being of the display signal level, the selecting signal level during each of said other fine scanning periods being reversed with respect to that of the preceding fine scanning period.

Preferably the scanning period is divided into two equal fine scanning periods, though it may be divided into more than two equal fine scanning periods or divided in disparate manner.

The apparatus may be made such that the values of the voltage levels in the selection signal for selection or non-selection can be varied, and/or such that the voltage levels in the display signal for effecting lighting or non-lighting of picture elements in the display can be varied.

The fine scanning periods need not together occupy a whole scanning time but may leave a cause period therein.

Means may be provided for effecting voltage or time modulation to enable the apparatus to produce a grey scale display.

According to this invention in another aspect a method of driving a liquid crystal matrix type electro-optical device by driving means including an element of non-linear characteristics and driving at least one substrate of a liquid crystal display panel by scanning it in two scanning frame periods with signals having alternating current bias, the two scanning frame periods together occupying a scanning period is characterised in that the average of the voltages applied to picture elements in a non-selected period during one frame period are made substantially equal in absolute value for all elements or parts thereof.

One method in accordance with the invention of driving a matrix type electro-optical display device is illustrated diagrammatically in Figure 7(A), (B) and (C). Figure 7(B) shows the waveform as used in a typical known driving system and Figure 7(C) shows, for comparison, the waveform used in carrying out the method in accordance with this invention. The driven display panel is represented in Figure 7(A) and is in the form of a matrix of display picture elements. In Figure 7(A), only one picture element (shown shaded) in column 5M and in row 6-O is shown as lit; every second picture element in row 6-N is shown as lit; and all the picture elements in row 6-P are also lit. In all the driving waveforms shown a 1/50 duty ratio with a 1/5 bias ratio (as is customary) is assumed. As will be seen from Figure 7(B), with the known generalised AC amplitude selective multiplexing method and scanning time T_s is

divided in half (because of the use of alternating current driving) and this is further divided among the 50 columns. Therefore the overall total division is by 100. The time unit 9 may be termed one "scanning period". The Scanning signal SCAN is at the selected level during one selected period Tsel once every half scanning period, and is at the non-selected level during other scanning periods.

On the other hand, with the driving method of this invention as shown in Figure 7(C), the one selected period Tsel in which the scanning signal is at the selected level during a half scanning period is further divided into a plurality of shorter periods. The time unit 10 may be termined one "fine scanning period". The scanning signal is at the selected level in one part of a fine scanning period, and at the non-selected level in other parts of the fine scanning period. In carrying out the invention one scanning period may be divided into fine scanning periods in different ways, in accordance with various different ratios, or in disparate intervals or in equal intervals. In the particular case now being described one scanning period is divided into equal halves.

As illustrated by Figure 7(C), SCAN M is the Mth scanning signal and will be seen to be a scanning signal of 1/100 duty ratio. The display signals which are applied to the display element rows 6-O, 6-N and 6-P are resepectively indicated by SIG O, SIG N and SIG P. One selected period Tsel of the display signal is divided into halves. Only a part of the fine scanning period 10 (in the case illustrated the first half) is taken at the same level as that of the generalized AC amplitude selective multiplexing method of Figure 7(B) and the other fine scanning period is taken at the reversed level. That is to say, the signal produced is such that the non-selected level is taken against the selected level and the selected level is taken against the non-selected level. As a result, the waveforms of the display signals which are applied to each display picture element 6-O, 6-N, 6-P are respectively SIG O, SIG N and SIG P. Thus the waveforms of the applied picture element voltage varies in the same way as 1/100 duty ratio centered on a standard level. The average values between selected periods and non-selected periods are almost all equal, as compared to those of a half-scanning period.

Figure 8(a), (b) and (c) respectively indicate by solid lines, the voltage VLC applied to the liquid crystal layer in relation to the voltage indicated by broken lines, respectively applied to the display picture elements (M, O), (M, N) and (M, P) as compared with the known driving method as illustrated in Figure 6, the VLC waveforms used in accordance with this invention and as shown in Figure 8 are almost equal discharge waveforms except for fine variations due to the display signal. Thus, the driving method of this invention effectively decreases to a very substantial extent variation of the effective voltage of the liquid crystal layer caused by the display signal.

As mentioned above, the effective voltage applied to the picture element is determined without being affected by ON—OFF switching on the same signal electrode. Therefore, a grey scale display, which is practically impossible to achieve with a known non-linear element driven liquid crystal display arrangement can, with this invention, be achieved by modulating the peak level in a selected period, or the timing of the selected level and peak level. Again the need for the close tolerances are regards voltage values—required in a known non-linear element driven liquid crystal display arrangement as regards the relation between the maximum effective voltage of the OFF waveform to the minimum effective voltage of the ON waveform is avoided. With the method of this invention, the tolerances as regards the required relation between the levels of the OFF waveforms and the ON waveforms are much less onerous. In a liquid crystal display arrangement in accordance with this invention multiplex driving of a multiple of N columns (e.g. of 2N columns) in fact occurs in the time hitherto occupied in the multiplex driving of N columns. Increase of the number of columns in a known arrangement is limited because of the increasingly severe tolerances which accompany such increase. However, with this invention increase of the number of columns is satisfactorily possible provided that there is enough time for charging the equivalent capacitance CLC of the liquid crystal layer to a sufficient level in the fine scanning period in which the peak voltage on the ON waveform is applied. In practice, it is possible to make this charging time very short indeed. It is possible to achieve a one thousandth duty ratio using an available non-linear element of suitable characteristic.

In the above described method in accordance with this invention one scanning period is divided into two equal parts. However, this particular division of the scanning period is not necessarily employed for the said period may be divided into a larger plurality of fine scanning periods, if there is a peak voltage in only one scanning period. Again this period may be divided into unequal parts. In other words one scanning period may be divided into any number of fine scanning periods, equal or unequal, so long as they are such as to provide enough time for charging the equivalent capacitance CLC to a sufficient level. However, the division of one scanning period into two equal parts is from the practical point of view, regarded as the best because of the simplicity of the driving circuitry required and the decrease of variation of the effective voltage achieved.

One scanning period does not have to be produced by dividing one scanning time *ts* into 2N equal parts, provided that the period wherein the scanning signal is at selected level is long enough to allow the equivalent capacitance CLC to be charged to a sufficient level in the selected period of the ON waveform. In other words, a period *x.ts* (where $o<x\leqq1$) which is shorter than one scanning time *ts* may be divided into 2N equivalent parts to produce one scanning period.

Figure 9 shows scanning signals SCAN 1 and

SCAN 8 and a display signal SIG 1 where N=8 and X=0.8, using a 1/5 bias ratio. In Figure 9, the display period *t*D covers eight scanning periods. The pause period tP is a time to which no scanning period appertains and in which all the signal electrodes are at the non-selected level. The display signal is in the pause period *tp* may be indicated not only by a non-selected waveform as shown but also by a selected waveform.

A further advantage of the invention is that there is a wide choice open to the designer as regards the selected level and the non-selected level chosen.

Figure 10 illustrates diagrammatically a liquid crystal display device and a driving system therefor. Referring to Figure 10, block 11 is a dot matrix liquid crystal panel; block 12 is a display element driver portion; block 13 is a scanning element driver portion; and block 14 is a driving signal generating portion. The liquid crystal panel 11 consists of scanning electrodes 15 and display electrodes 16. The display electrode driver portion 12 consists of a shift register arrangement 17 giving J steps (where J is the number of display signal electrodes); J latching circuits 18—these are latching circuits composed of J flip-flops—coupled to the flip-flops in the shift register; a level shifter 19 which converts logic levels to liquid crystal display levels; and J demultiplexers 20 which switch between lighting and non-lighting display signal levels under the control of the signals from the level shifter 19. The scanning electrode driver portion 13 comprises a shift register 21 composed of 2K flip-flops, (where K is the number of scanning electrodes) providing 2N steps; a level shifter 22; and a K demultiplexer 23 which switches between selecting the non-selecting scanning signals under the control of the signals from the level shifter 22. The driving pulse generating portion 14 consists of demultiplexers 24 to 29 and resistors 30 to 34 in a potentiometer which produces driving voltages for the demultiplexers 24 to 26. Operation of the apparatus shown in Figure 10 will now be explained with the aid of the timing waveform diagrams of Figures 11 and 12(a) and (b). In Figure 11 ϕs is a clock pulse waveform from the shift register 17. Display data DATA is clocked by the pulse ϕs. When J items of data for one line are transmitted, a clock pulse CLe from the latching circuit 18 of high level appears and data is latched from the shift register 17 to the latching circuit 18. The level of the data is shifted by the level shifter 19 and fed in to a control terminal of the multiplexer 20. Multiplexer 20 switches the display signals DON or DOFF delivered from the driving signal generating portion 14 in accordance with the display data signal. The D SCAN signal, which becomes high once a frame period, (which is one half the scanning time t_s) is delivered to the shift register 21 of the scanning electrode driver 13 by the scanning clock signal CLSC. As shown in Figure 11 the scanning clock signal CLSC produced from the RS flip-flop 32 (Figure 13) has the doubled frequency CL1. The odd numbered step outputs of the 2K flip-flops of the shift register 21 are fed to a level shifter 22. Odd numbered step outputs such as SC1, SC2 and SC3 are indicated in Figure 12 (a). These outputs are supplied to the demultiplexer 23 through the level shifter 22. Demultiplexer 23 switches the selecting signal SC ON or the non-selecting signal SC OFF under the control of the signal SC1, SC2. . . .SCK. Resistors 30 to 34 divide a supply voltage of —5V into voltages of —V to —5V as indicated in Figure 10. Demultiplexers 24 and 25 switch the levels of the scanning signal in accordance with the frequency of the signal ϕ for driving the liquid crystal with an alternating current and the selecting signal SC ON and the non-selecting signal SC OFF are produced. Demultiplexers 26 and 27 produce the selecting signal DSEL and the non-selecting signal DNSEL in accordance with the frequency of the signal ϕf. Demultiplexers 28 and 29 switch the selecting signal DSEL and the non-selecting signal DNSEL by the clock signal 1/2 CL SC which is produced by dividing the clock signal CL SC by two. Thus signals DON and DOFF for a display electrode and as shown in Figure 12(b) are produced.

Figure 13 is a block diagram of a controlling circuit which generates clock pulses for a driving circuit arrangement in accordance with this invention and in which J=160 and K=120. The circuit comprises a 6-bit binary counter 30; a NOR gate 31; an RS flip-flop 32; an inverter 33; D type flip-flops 34, 35, 39 and 41; NOR gates 36 and 40; a 6-bit binary counter; and an AND gate 38. The binary counter 30 counts clock pulse ϕs supplied to the shift register 17 of the display electrode driver 12. Counting is completed when J/2=80 and this is detected by the gate 31 which sets the RS-FF 32. RS-FF 32 is synchronised to be reset by a leading edge of the signal ϕsto. The output from the RS flip-flop 32 is fed into the reset terminal R of counter 30 and to the D type FF 34. This flip-flop 34 divides the clock pulse by two to produce the signal 1/2 CL SC which is supplied to the data input D of the flip-flop FF 35. The signal 1/2 CL SC is processed by the D type 35 and the NOR gate 36 to constitute a signal CLR of one scanning period and is supplied to the clock pulse input terminal of the latching circuit 18. After counter 37 has made a count of 239 of the clock pulses CL SC from the RS flip-flop 32, the output from the AND gate 38 becomes of high level. This high level signal is delayed by the D type flip-flop 39 to constitute a delay signal D SCAN for the shift register 21 in the scanning electrode driver and then fed by gate 40 to the D type flip-flop 41. This pulse constitutes the signal ϕf which alternately becomes high and low per half the scanning period—i.e. per frame period—and is supplied to the demultiplexers 25 to 26 in the driving signal generating portion 14 (Figure 10).

As will now be appreciated the driving method of this invention can be achieved by relatively simple circuitry. The variation of the effective

voltage in dependence upon whether picture elements are in the lit or the unlit state is much decreased, so that the minimum value of E ON can be made high and the maximum of E OFF can be made low and thereby the difference between them can be made small. And, finally, a liquid crystal displayed device driven by a non-linear driving arrangement in accordance with this invention can be satisfactorily employed to give a grey scale display of good quality display over the display panel.

Claims

1. An electric-optical matrix type liquid crystal display device and a non-linear driving and addressing system therefor wherein the time during which selection of a picture element is effected is shortened and the average value of the driving voltage during non-selected periods is maintained substantially free of variation by dividing the scanning period as herein defined into at least two fine scanning periods as herein defined, the voltage applied during at least one fine scanning period in a scanning period being of one pre-determined level and that applied during other fine scanning periods being of the display signal level, the selecting signal level during each of said other fine scanning periods being reversed with respect to that of the preceding fine scanning period.

2. Apparatus as claimed in claim 1 wherein the scanning period is divided into two equal fine scanning periods.

3. Apparatus as claimed in claim 1 wherein the scanning period is divided into more than two equal fine scanning periods.

4. Apparatus as claimed in claim 1 wherein the division of the scanning period into fine scanning periods is disparate.

5. Apparatus as claimed in any of the preceding claims and which is such that the values of the voltage levels in the selection signal for selection or non-selection can be varied.

6. Apparatus as claimed in any of the preceding claims and which is such that the voltage levels in the display signal for effecting lighting or non-lighting of picture elements in the display can be varied.

7. Apparatus as claimed in claim 1 wherein the fine scanning periods do not together occupy a whole scanning time but leave a pause period therein.

8. Apparatus as claimed in any of the preceding claims and including means for effecting voltage or time modulation to enable the apparatus to produce a grey scale display.

9. A method of driving a liquid crystal matrix type electro-optical device by driving means including an element of non-linear characteristics and driving at least one substrate of a liquid crystal display panel by scanning it in two scanning frame periods with signals having alternating current bias, the two frame scanning periods together occupying a scanning period, characterised in that the average of the voltages applied to picture elements in a non-selected period during one frame period are made substantially equal in absolute value for all elements or parts thereof.

10. A method as claimed in claim 9, wherein all or part of each half-scanning period is equally divided by the number of scanning electrodes to constitute a certain period which is further divided into a plurality of fine scanning periods, the scanning signal applied being at a selecting level in some fine scanning periods during said certain period and a non-selecting level in the remaining fine scanning periods during said certain period.

11. A method of driving liquid crystal display as claimed in claim 9 or 10, wherein the display signal applied is respectively at lighting level or at nonlighting level in dependence upon whether the picture element is in the ON or OFF condition in a period synchronised with the fine scanning period and said scanning signal is at selecting level, said display signal being respectively at the non-lighting level or at lighting level in converse correspondence with the condition of the picture element in another period synchronized with the remaining fine scanning period in the scanning period.

12. A method as claimed in claim 9, 10 or 11, wherein the times in which the selecting and the nonselecting levels occur are equal, said selecting level being applied in some of the fine scanning periods produced by dividing the scanning period and said non-selecting level being applied in the remaining fine scanning periods.

13. A method of driving liquid crystal display device as claimed in any of claims 9 to 12, wherein said fine scanning period is divided in half.

14. Methods of driving matrix type liquid crystal display devices and apparatus for putting such methods into effect substantially as herein described with reference to Figures 7 to 13 inclusive of the accompanying drawings.

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