(12) **UK Patent Application** (19) **GB** (11) **2 185 614** (13)**A**

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(71) Applicant
Canon Kabushiki Kaisha,

(Incorporated in Japan),

30-2 3-chome Shimomaruko, Ohta-ku, Tokyo, Japan

(72) Inventors
Akihiro Mouri,
Tsutomu Toyono,
Shuzo Kaneko,
Yukata Inaba,
Junichiro Kanbe

(54) **Driving method for optical modulation device**

(57) A matrix optical modulation display device is driven in a writing period for writing in all or prescribed pixels on a selected scanning electrode, in a first phase t_1 for applying a voltage of one polarity of an amplitude exceeding a first threshold voltage a third phase t_3 for applying a voltage of the other polarity having an amplitude exceeding a second threshold voltage to a selected pixel and an intermediate second phase not affecting the pixel state. The duration of a continually applied voltage of the same polarity applied to a pixel on a scanning electrode is 2.5 times the duration of the first phase in the writing period at the maximum so that an unintended change in pixel state does not occur with passage of time. The voltages applied to unselected pixels are of alternating polarity and below either threshold voltages. A fourth phase not causing a change of state may be provided. The modulation material may be a ferroelectric liquid crystal with bistable characteristics.
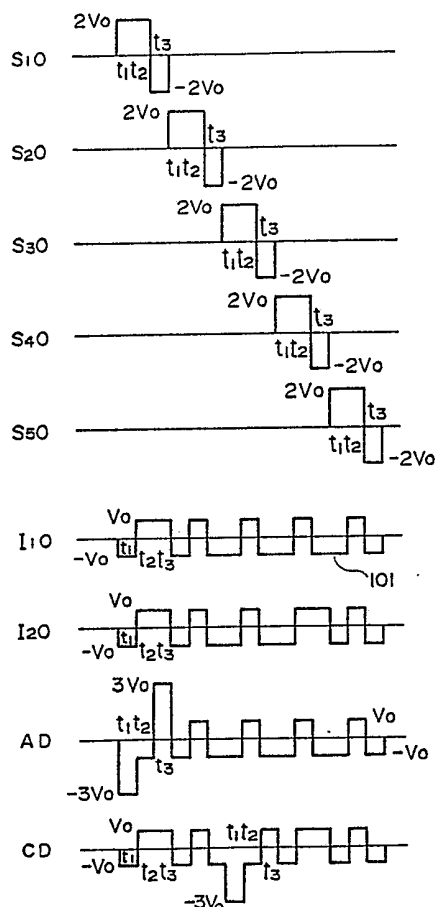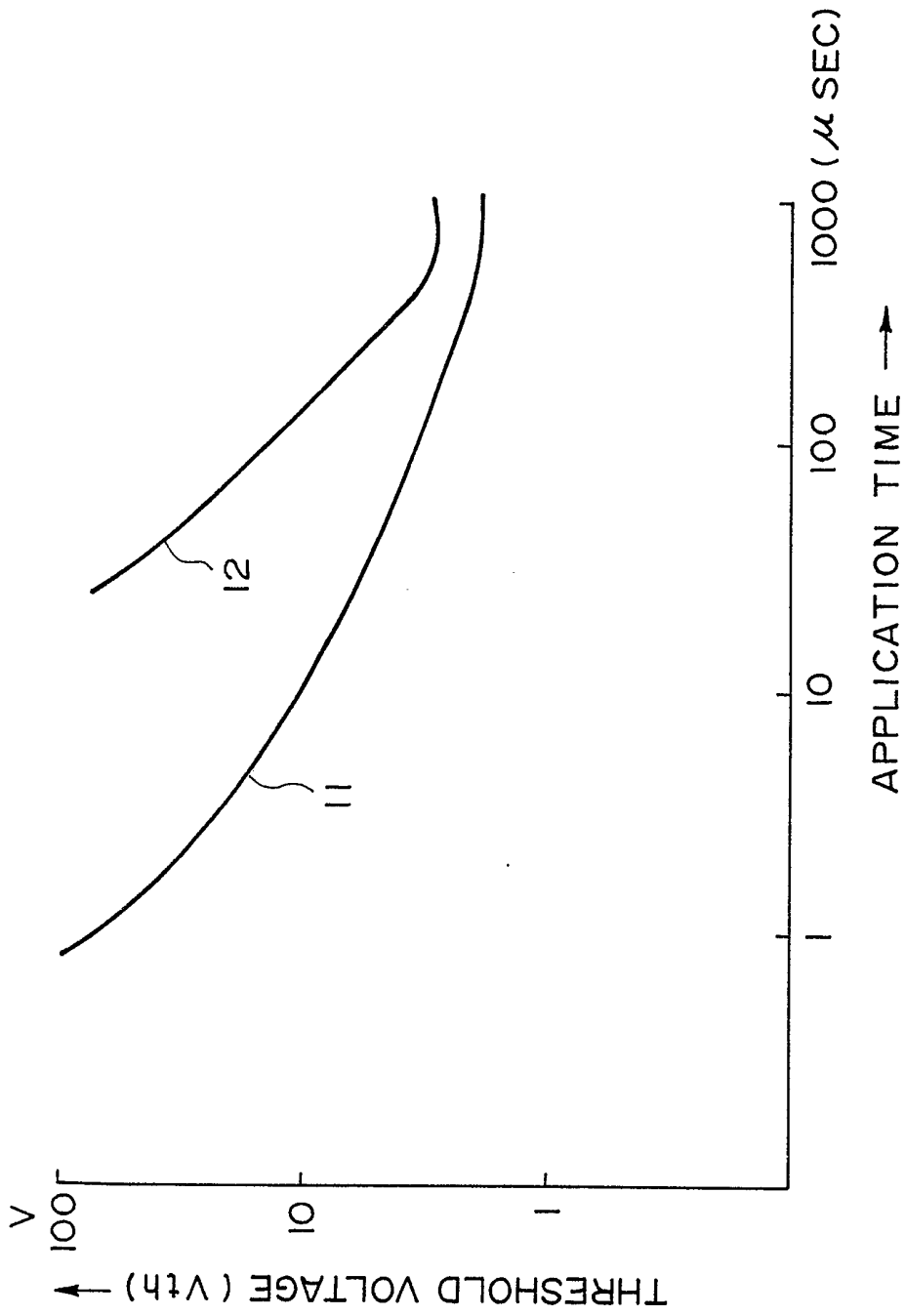
FIG. 10

GB 2 185 614 A

FIG. 1

THRESHOLD VOLTAGE (Vth) →

V
100

10

1

APPLICATION TIME →

1

10

100

1000 (μ SEC)

I1

I2

24(P⊥)

22

23

23

21b

F I G. 2

21a

34a(Pa)   33a   22   21b

Ea   Eb

34b(Pb)   33b

F I G. 3

$\underline{43}$

I_1 I_2 I_3 I_4 I_5 ------

A

B

S_1

$\underline{41}$

S_2

S_3

C

$\underline{42}$

S_4

S_5

F I G. 4

F I G. 5A

$2V_0$

t_3

O

t_1+t_2

$-2V_0$

F I G. 5B

O

$t_1+t_2+t_3$

F I G. 5C

t_2

V_0

O

$-V_0$

t_1 t_3

F I G. 5D

t_1 t_3

V_0

O

$-V_0$

t_2

FIG. 6A

$3V_0$

V_0

O --- t_1 t_2 t_3 ---

$-3V_0$

FIG. 6B

$3V_0$

V_0

O --- t_1 t_2 t_3 ---

$-V_0$

FIG. 6C

V_0

O --- t_1 t_2 t_3 ---

$-V_0$

FIG. 6D

V_0

O --- t_1 t_2 t_3 ---

$-V_0$
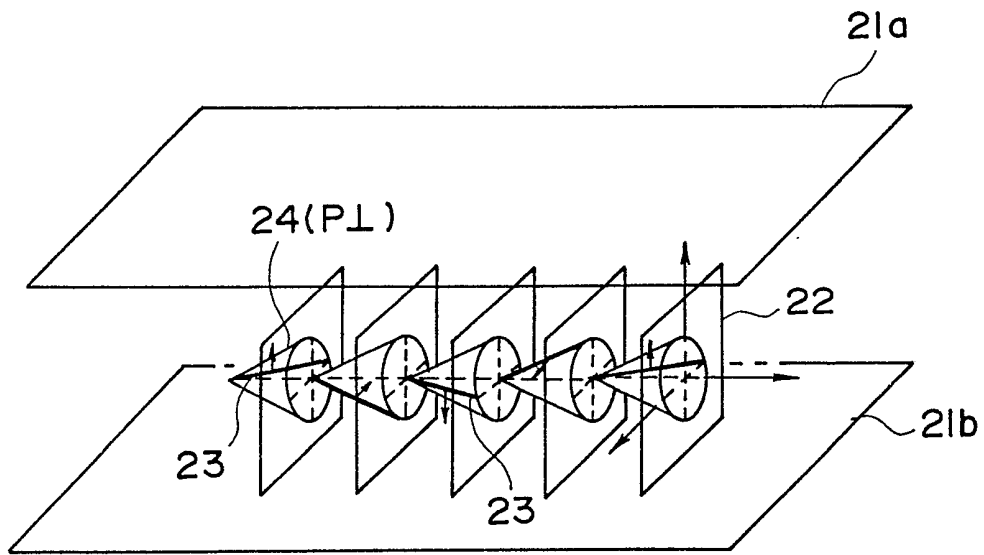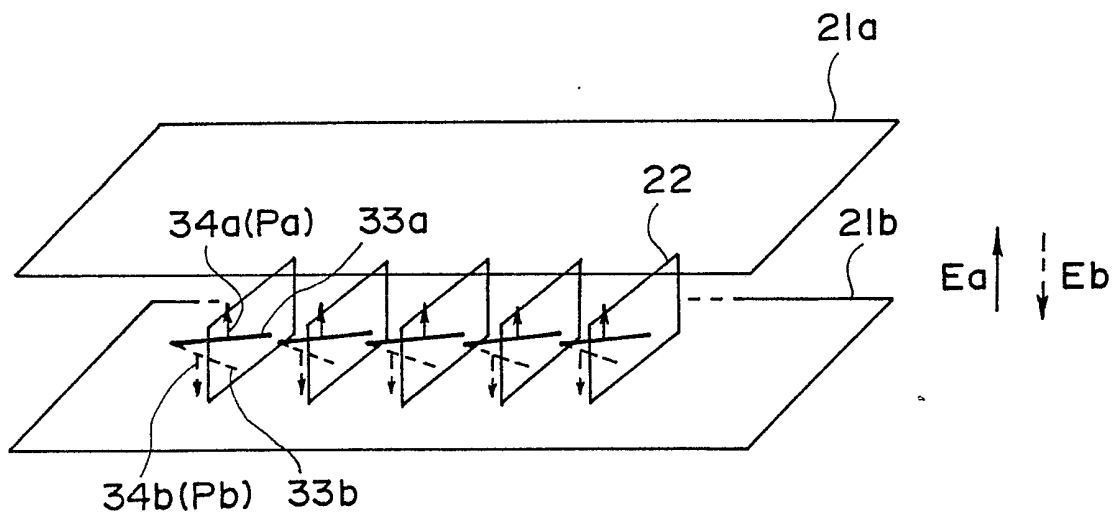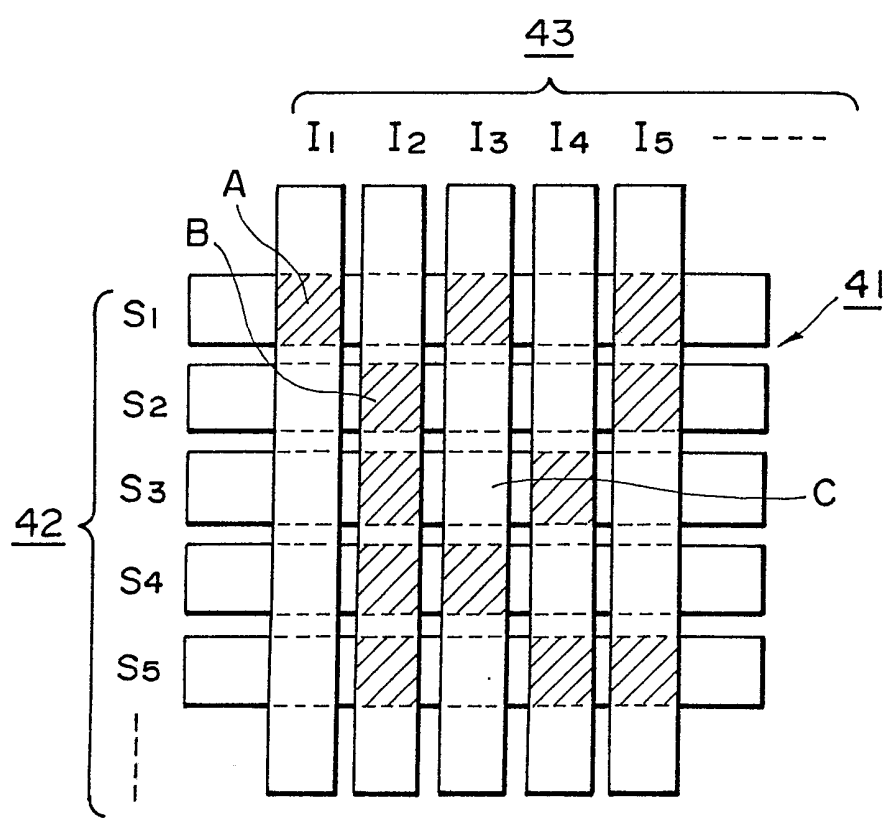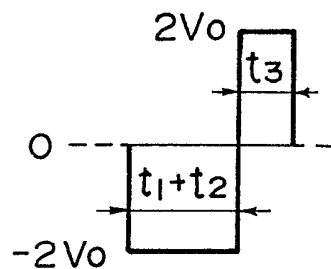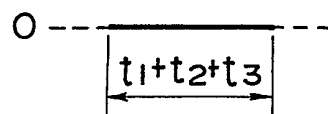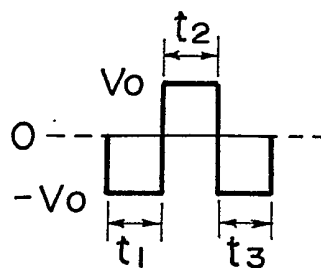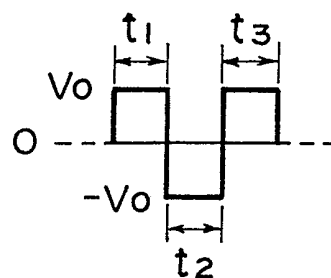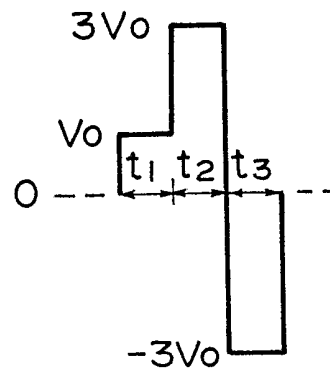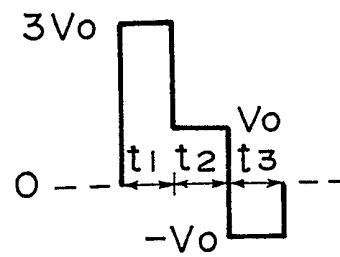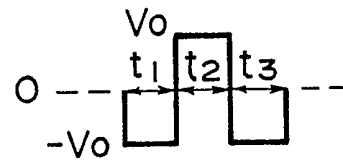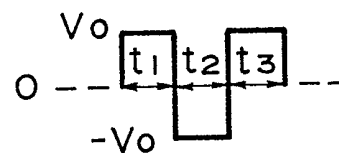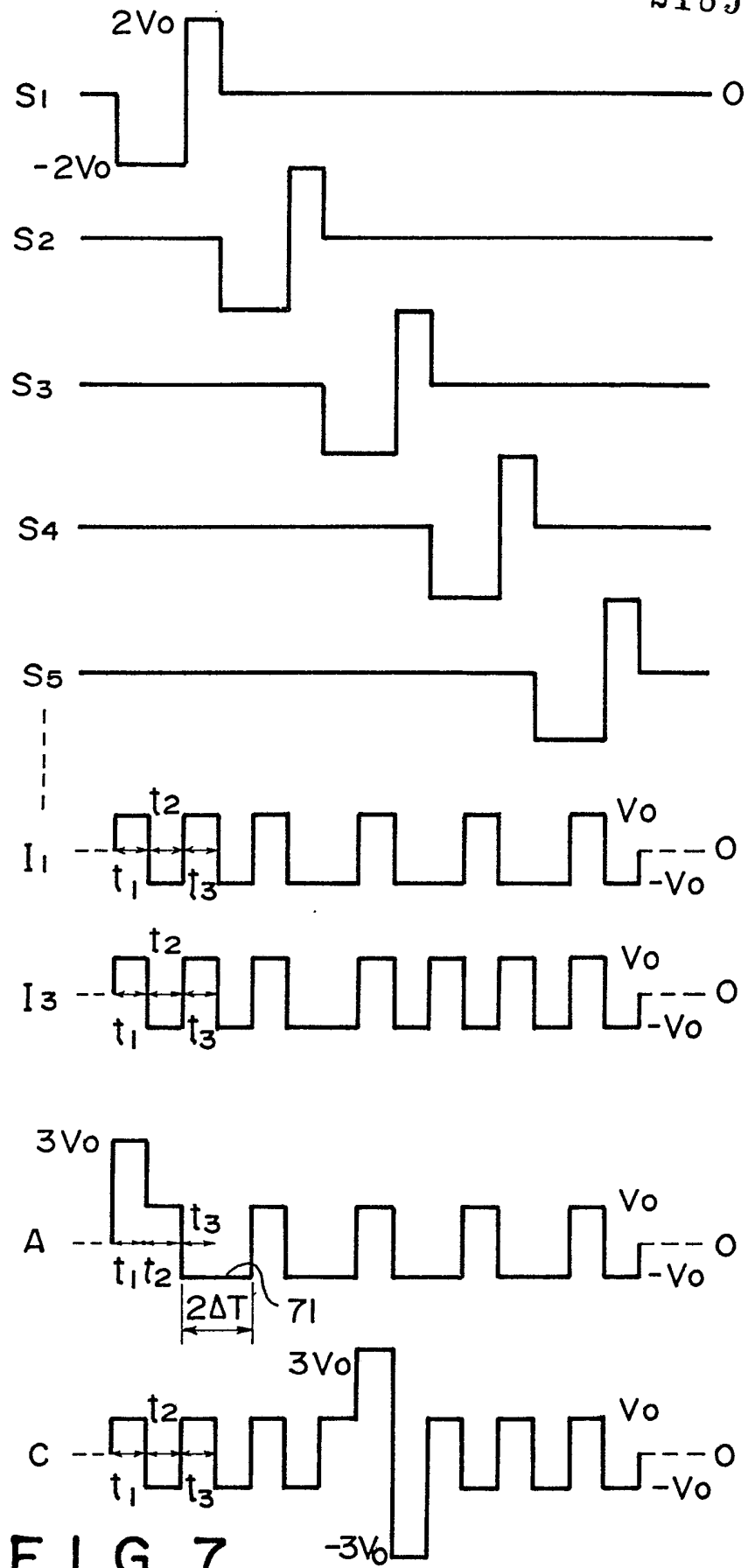
F I G. 7

F I G. 8A
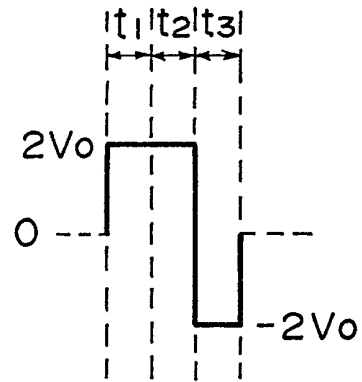
F I G. 8B

F I G. 8C
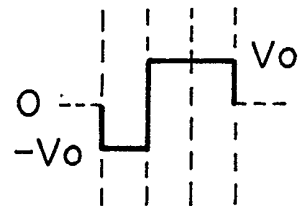
F I G. 8D

FIG. 9A

FIG. 9B

FIG. 9C

FIG. 9D

S1O

2Vo

t3

t1 t2

-2Vo

S2O

2Vo

t3

t1 t2

-2Vo

S3O

2Vo

t3

t1 t2

-2Vo

S4O

2Vo

t3

t1 t2

-2Vo

S5O

2Vo

t3

t1 t2

-2Vo

I1O

Vo

-Vo

t1

t2 t3

101

I2O

Vo

-Vo

t1

t2 t3

AD

3Vo

t1 t2

t3

Vo

-Vo

-3Vo

CD

Vo

-Vo

t1

t2 t3

t1 t2

t3

-3Vo

F I G. 10

F I G. IIA

$2V_0$

O

$-2V_0$

F I G. IIB

O

F I G. IIC

V_0

O

$-V_0$

F I G. IID

V_0

O

$-V_0$
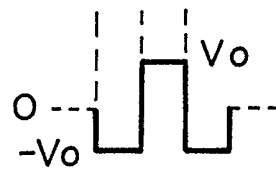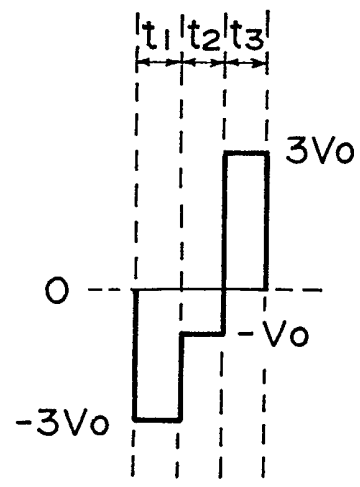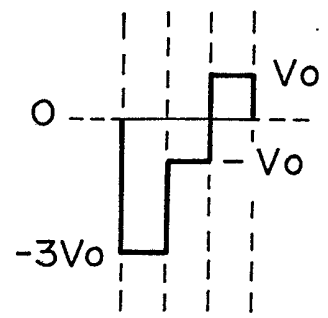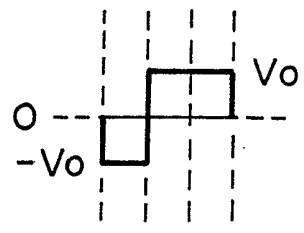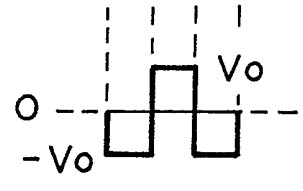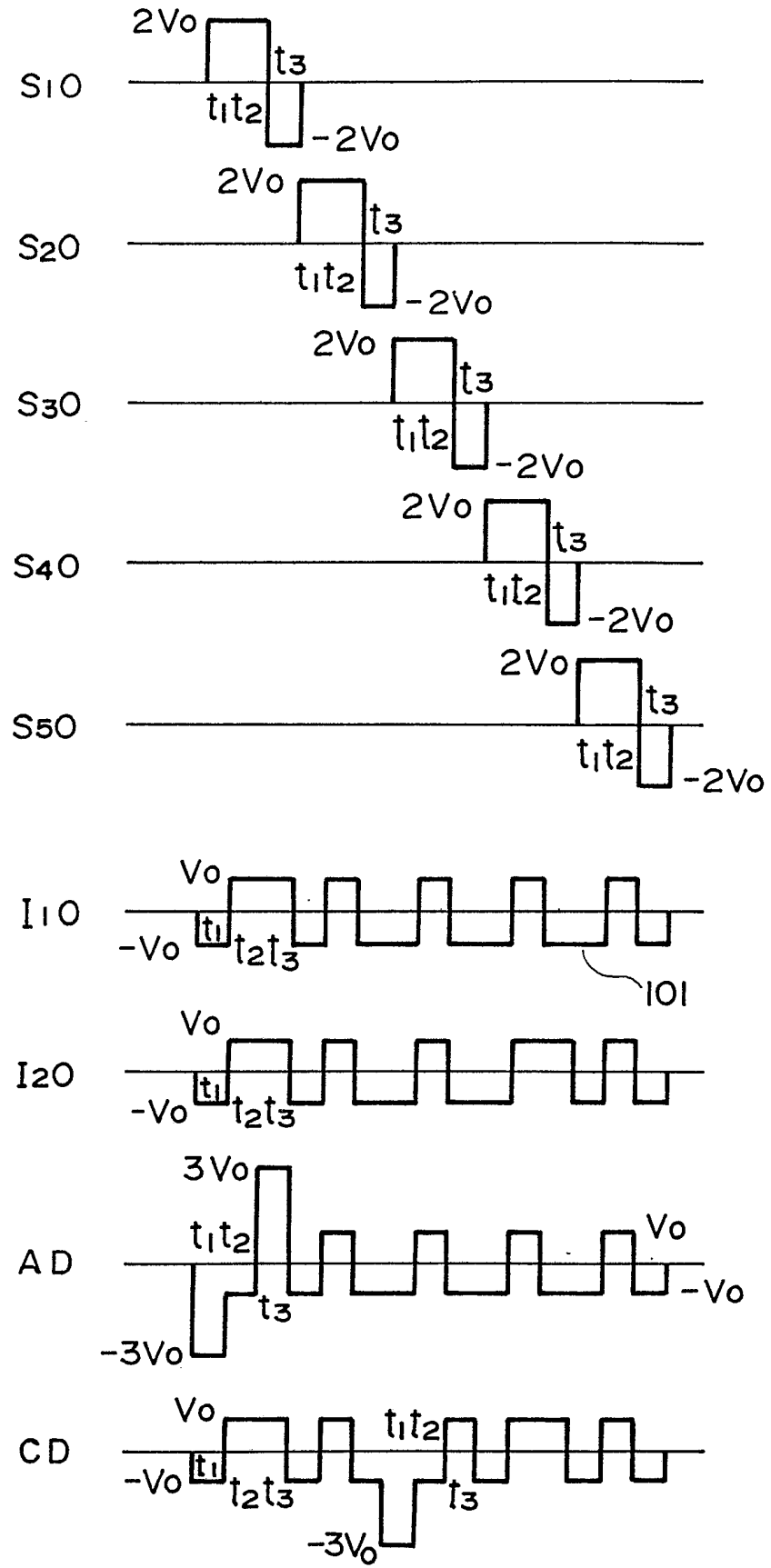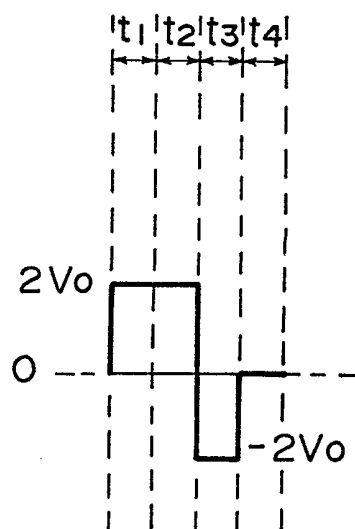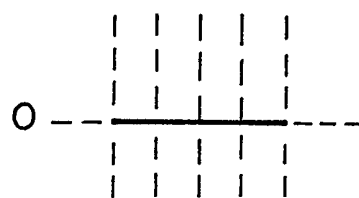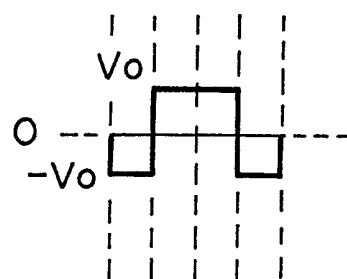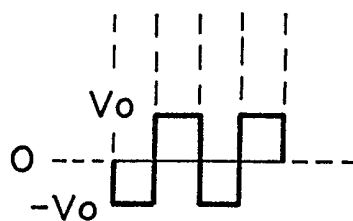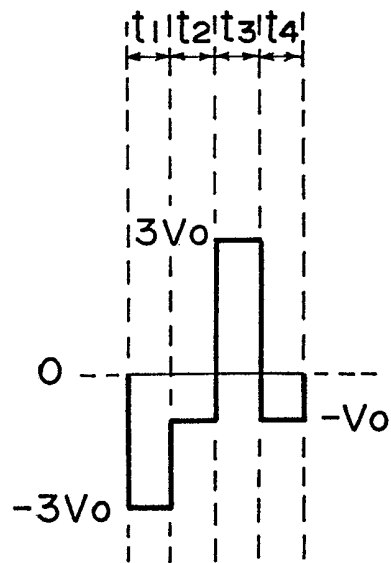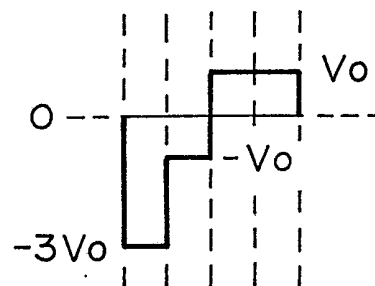
FIG. 12A

FIG. 12B

FIG. 12C

FIG. 12D
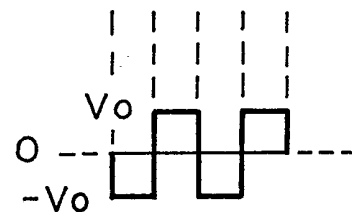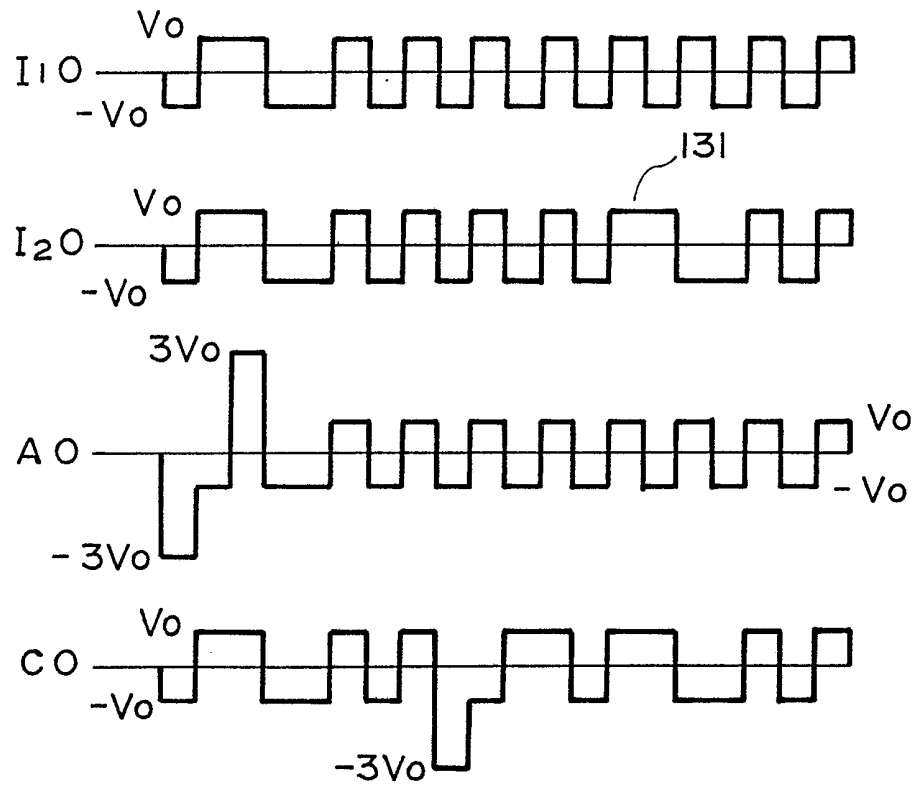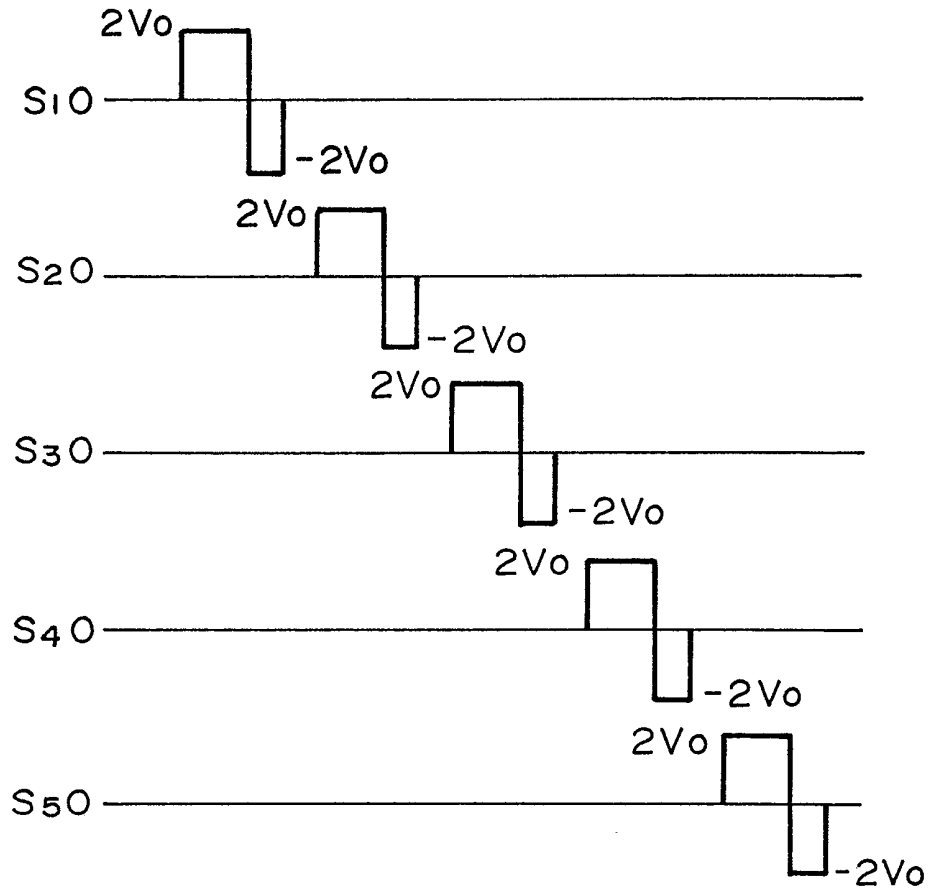
F I G. 13

FIG. 14A
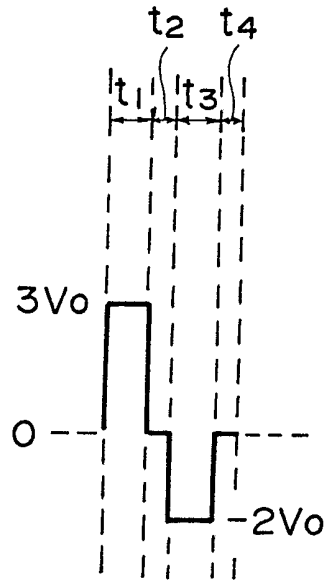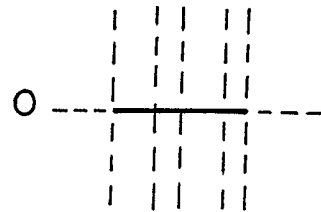
$3V_0$

O

$-2V_0$

t_1 t_2 t_3 t_4

FIG. 14B

O

FIG. 14C

V_0

O

$-V_0$

FIG. 14D

V_0

O

$-V_0$

F I G. I5A

F I G. I5B

F I G. I5C

F I G. I5D

F I G. 16

t_1 t_2 t_3

F I G. 17A

$2V_0$

0

$-2V_0$

F I G. 17B

0

F I G. 17C

0

V_0

$-V_0$

F I G. 17D

0

V_0

$-V_0$
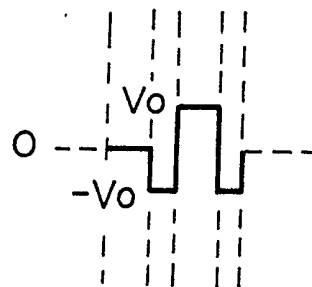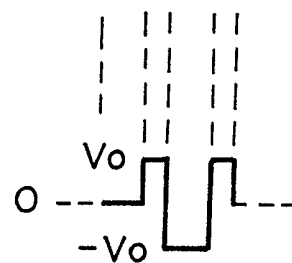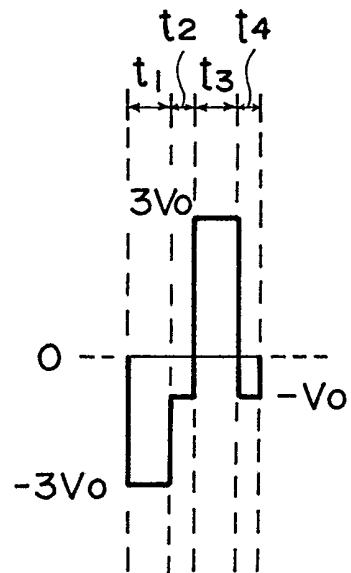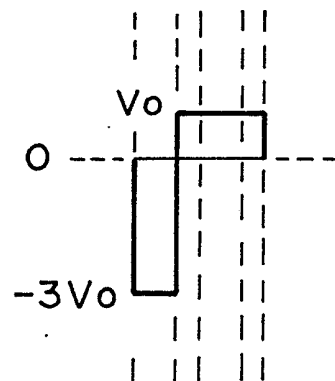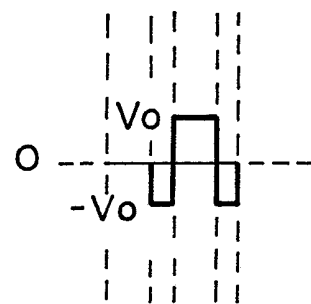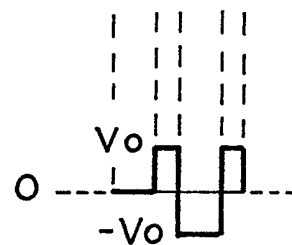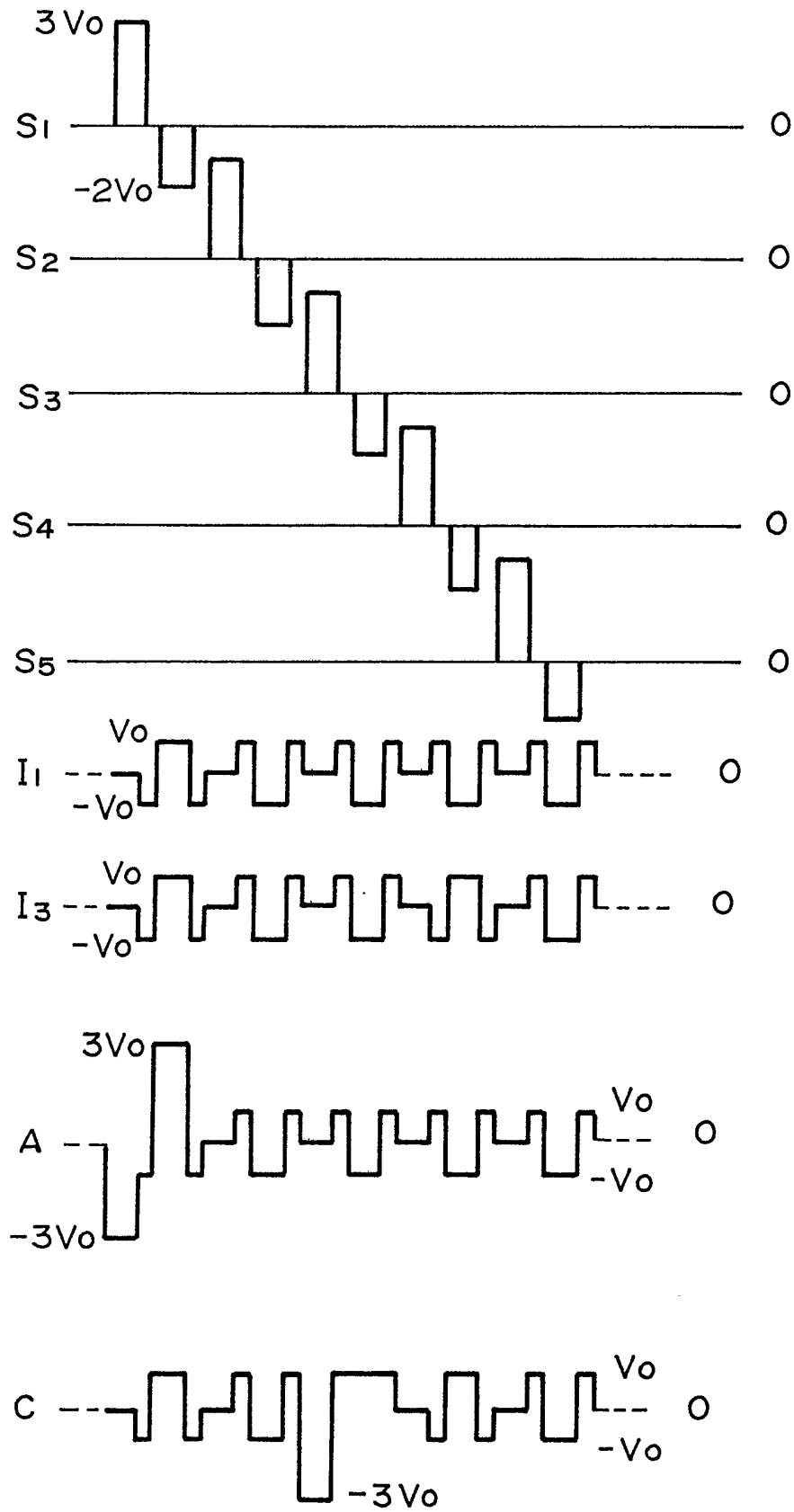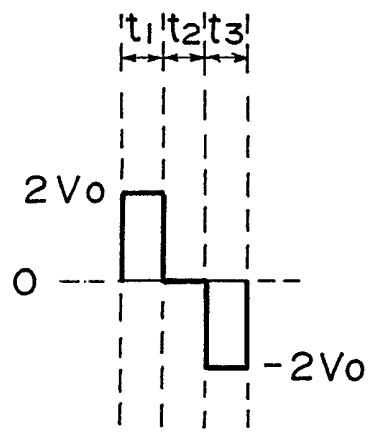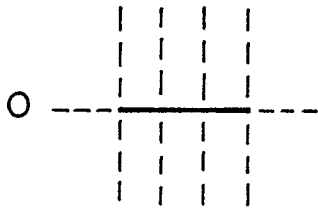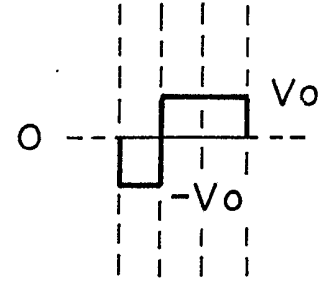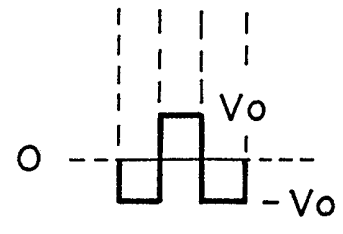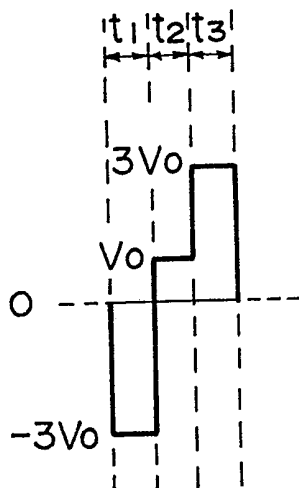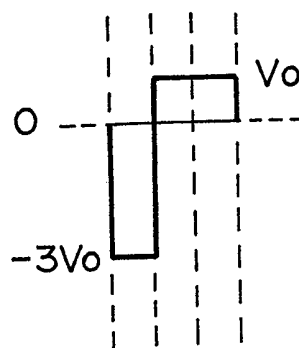
FIG. 18A
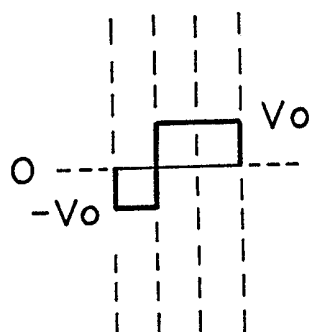
FIG. 18B

FIG. 18C

FIG. 18D
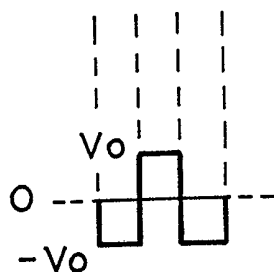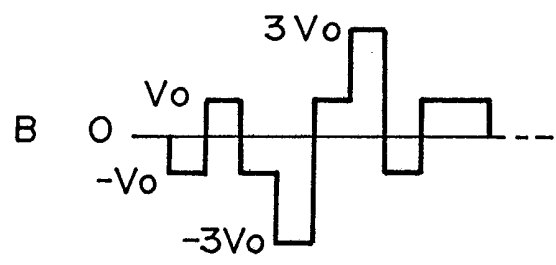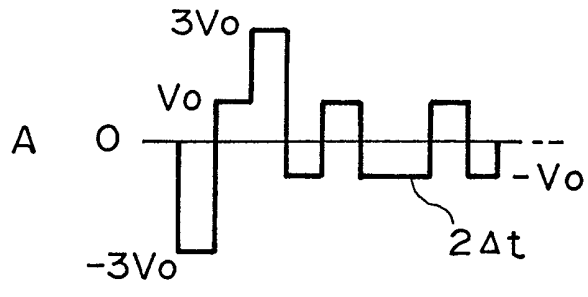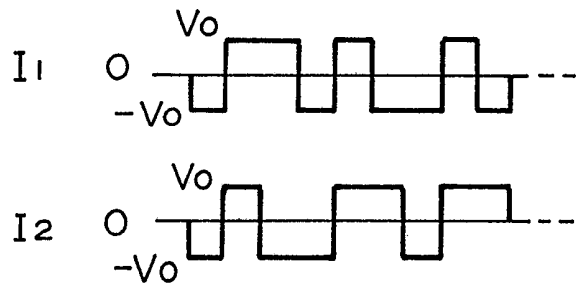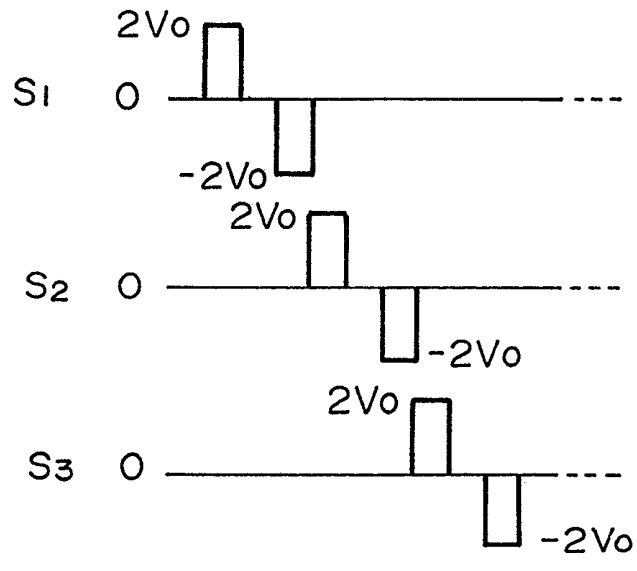
F I G. 19

F I G. 20A
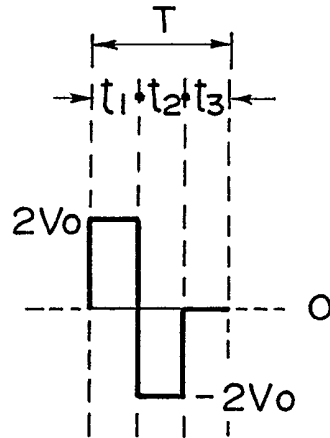
F I G. 20B
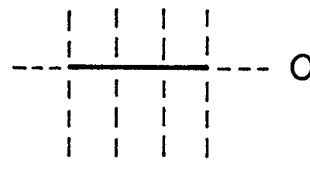
F I G. 20C
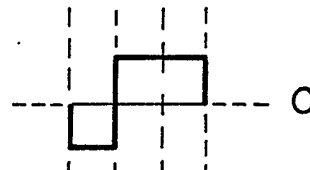
F I G. 20D
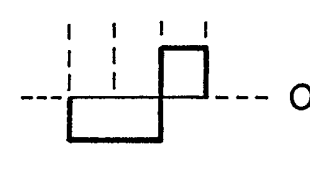
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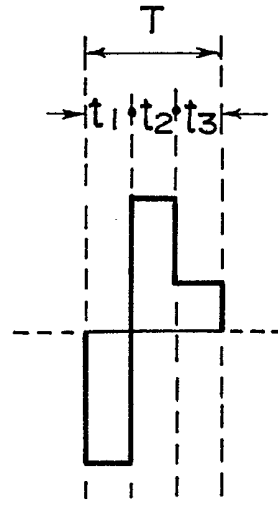
F I G. 21B
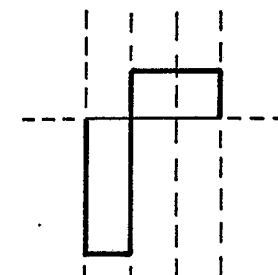
F I G. 21C
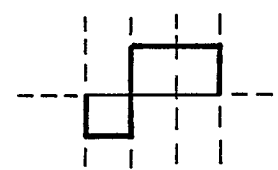
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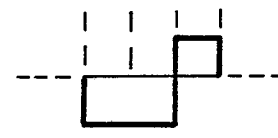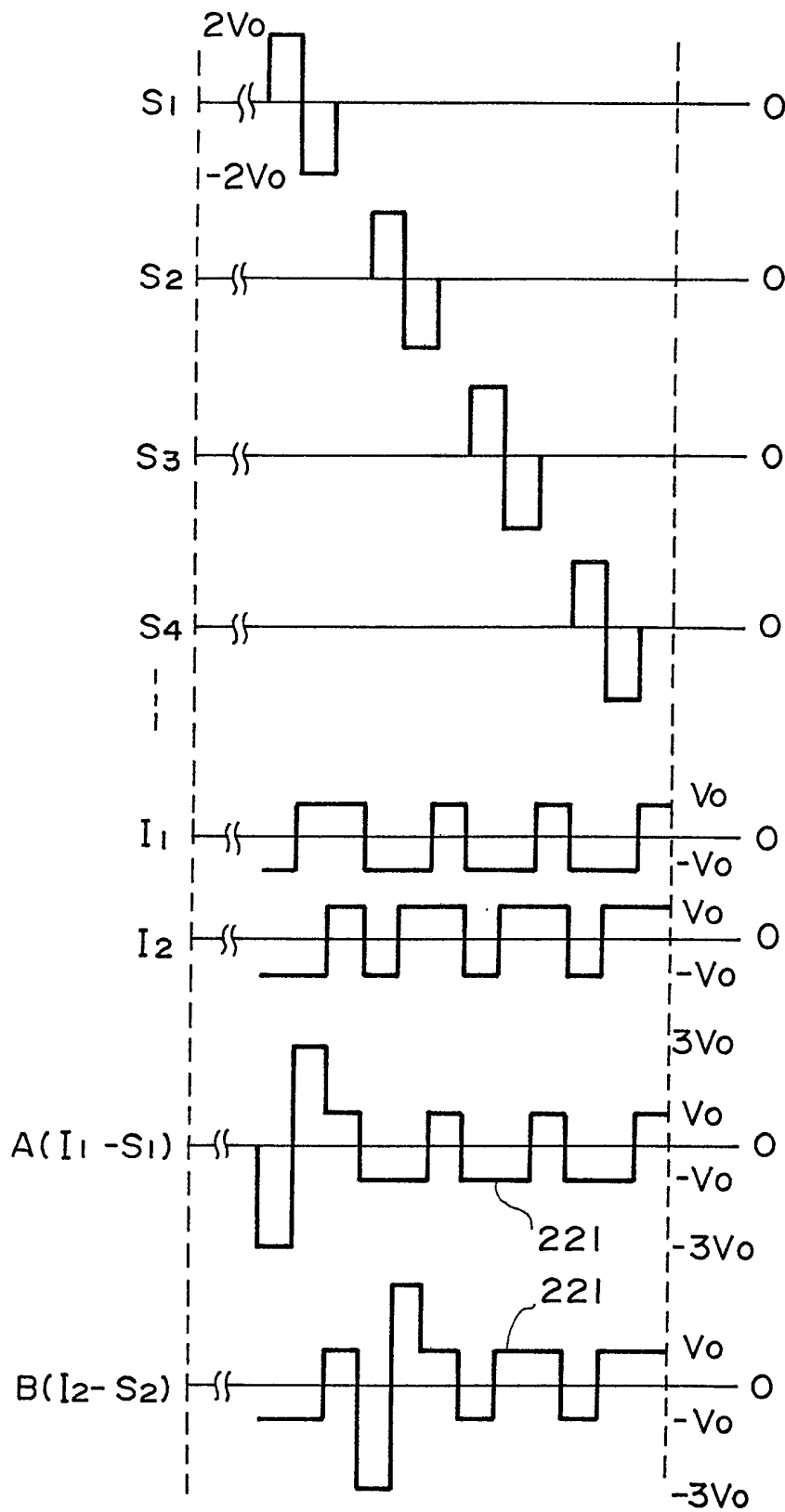
F I G. 22

F I G. 23A
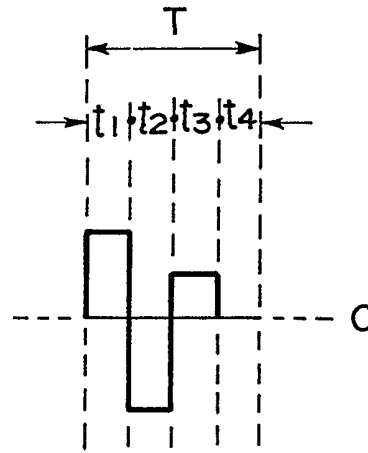
F I G. 23B
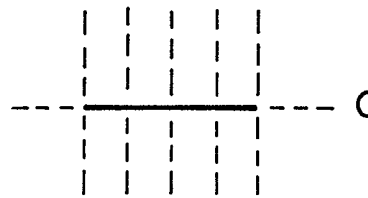
F I G. 23C
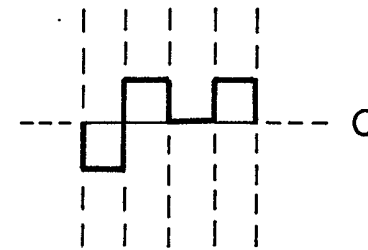
F I G. 23D
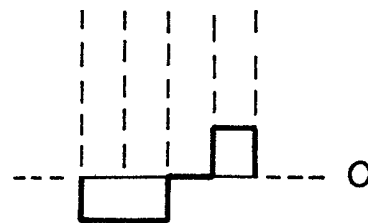
F I G. 24A
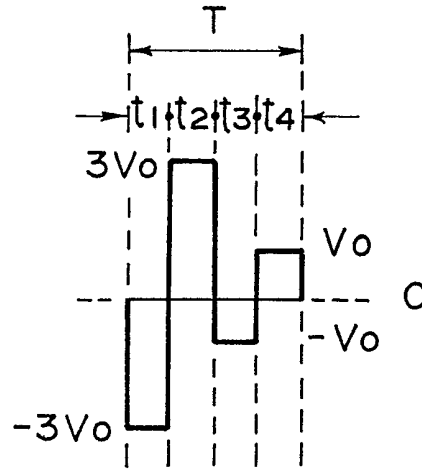
F I G. 24B
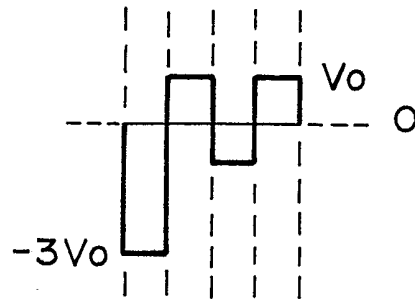
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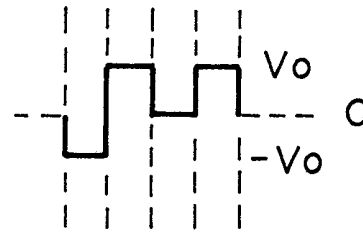
F I G. 24D
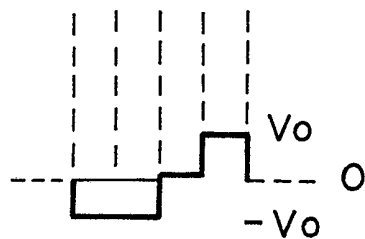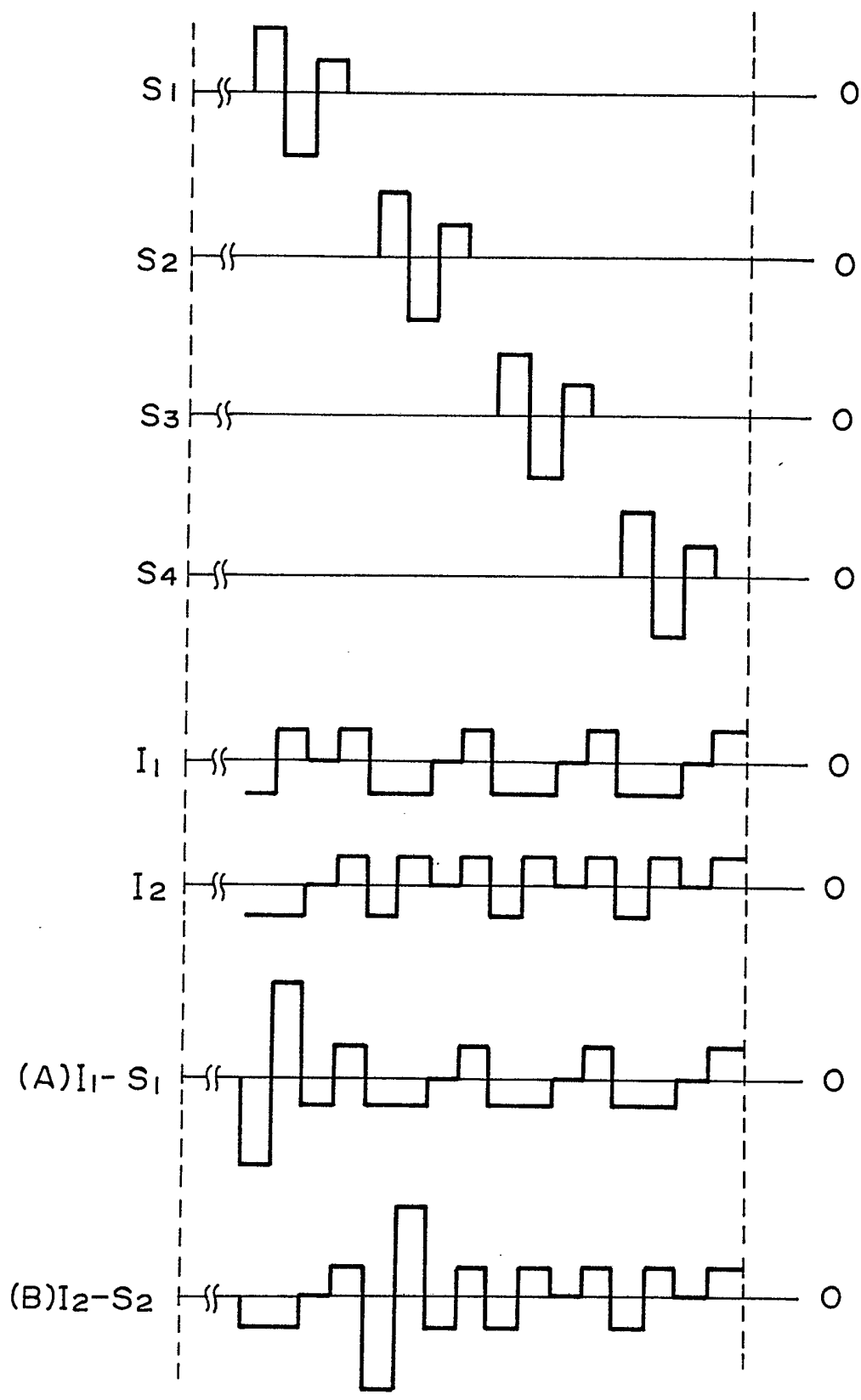
F I G. 25

T(Δt)

2Vo

O

F I G. 26A

F I G. 26B

O

-Vo

F I G. 26C

O

-3Vo

$t_1(\Delta t)$

$t_2(\Delta t)$

F I G. 27A

$2V_0$

O

$-2V_0$

F I G. 27B

O

F I G. 27C

V_0

O

$-V_0$

F I G. 27D

V_0

O

$-V_0$

$t_1(\Delta t)$

$t_2(\Delta t)$

F I G. 28A

$3V_0$

O

$-3V_0$

F I G. 28B

V_0

O

$-V_0$

F I G. 28C

V_0

O

$-V_0$

F I G. 28D

V_0

O

$-V_0$
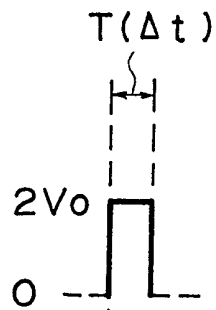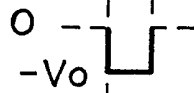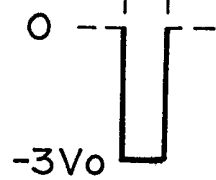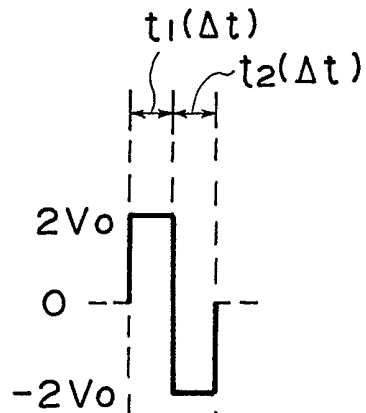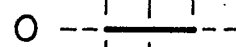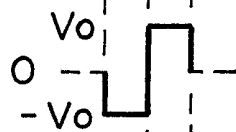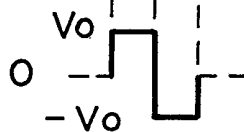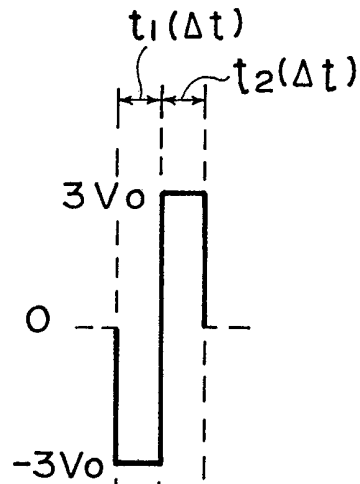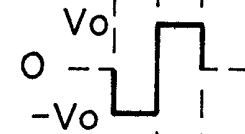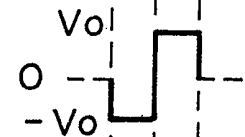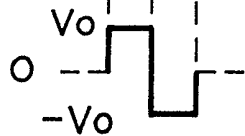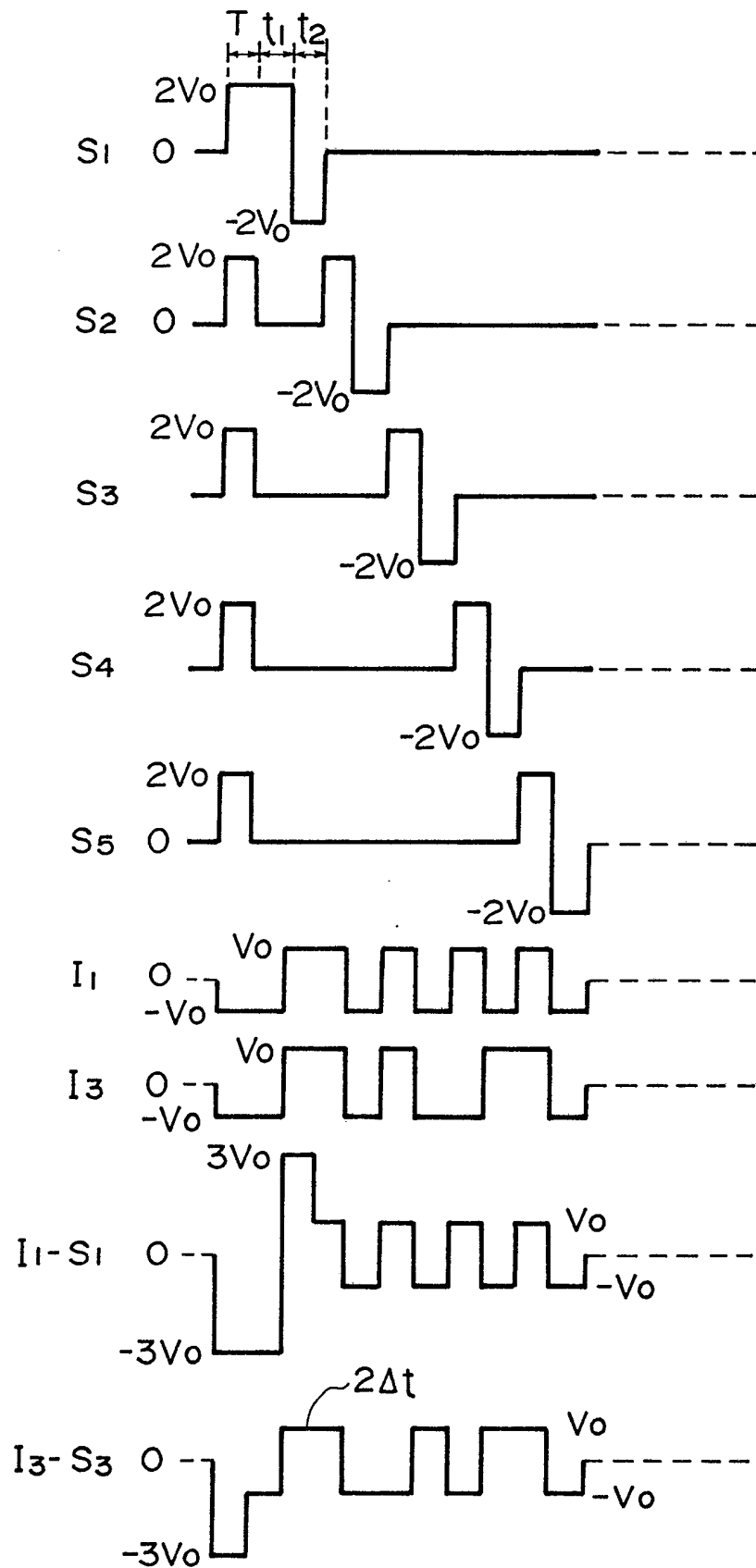
F I G. 29
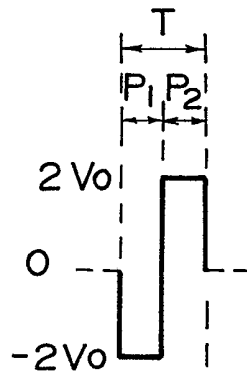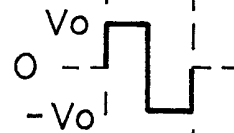
F I G. 30A

F I G. 30B

F I G. 30C
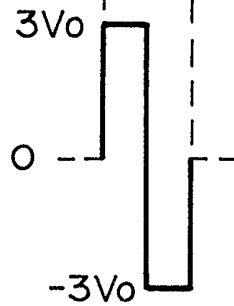
SPECIFICATION

Driving method for optical modulation device

5 *Field of the invention and related art*   5
The present invention relates to a driving method for an optical modulation device in which a contrast is discriminated depending on the direction of an applied electric field, particularly a driving method for a ferroelectric liquid crystal device showing at least two stable states.
Hitherto, there is well known a type of liquid crystal device wherein scanning electrodes and signal elec-
10 trodes are arranged in a matrix, and a liquid crystal compound is filled between the electrodes to form a large   10
number of pixels for displaying images or information. As a method for driving such a display device, a time-division or multiplex driving system wherein an address signal is sequentially and periodically applied to the scanning electrodes selectively while prescribed signals are selectively applied to the signal electrodes in a parallel manner in phase with the address signal, has been adopted.
15   Most of liquid crystals which have been put into commercial use as such display devices are TN (twisted   15
nematic) type liquid crystals, as described in "Voltage-Dependent Optical Activity of a Twisted Nematic Liquid Crystal" by M. Schadt and W. Helfrich, Applied Physics Letters Vol. 18, No. 4 (Feb. 15, 1971) pp. 127-128.
In recent years, as an improvement on such conventional liquid crystal devices, the use of a liquid crystal
20 device showing bistability has been proposed by Clark and Lagerwall in Japanese Laid-Open Patent Applica-   20
tion No. 107216/1981, U.S. Patent No. 4367924, etc. As bistable liquid crystals, ferro-electric liquid crystals showing chiral smectic C phase (SmC*) or H phase (SmH*) are generally used. These liquid crystal materials have bistability, i.e., a property of assuming either a first stable state or a second stable state and retaining the resultant state when the electric field is not applied, and has a high response speed in response to a change in
25 electric field, so that they are expected to be widely used in the field of a high speed and memory type display   25
apparatus, etc.
However, this bistable liquid crystal device may still cause a problem, when the number of picture el-ements is extremely large and a high speed driving is required, as clarified by Kanbe et al in GB-A 2141279. More specifically, if a threshold voltage required for providing a first stable state for a predetermined voltage
30 application time is designated by $-V_{th1}$ and one for providing a second stable state by V_{th2} respectively for a   30
ferroelectric liquid crystal cell having bistability, a display state (e.g., "white") written in a picture element can be inverted to the other display state (e.g., "black") when a voltage is continuously applied to the picture element for a long period of time.
Figure 1 shows a threshold characteristic of a bistable ferroelectric liquid crystal cell. More specifically,
35 Figure 1 shows the dependency of a threshold voltage (V_{th}) required for switching of display states on voltage   35
application time when HOBACPC (showing the characteristic curve 11 in the figure) and DOBAMBC (showing curve 12) are respectively used as a ferroelectric liquid crystal.
As apparent from Figure 1, the threshold voltage V_{rh} has a dependency on the application time, and the dependency is more marked or sharper as the application time becomes shorter. As will be understood from
40 this fact, in case where the ferroelectric liquid crystal cell is applied to a device which comprises numerous   40
scanning lines and is driven at a high speed, there is a possibility that even if a display state (e.g., bright state) has been given to a picture element at the time of scanning thereof, the display state is inverted to the other state (e.g., dark state) before the completion of the scanning of one whole picture area when an information signal below V_{th} is continually applied to the picture element during the scanning of subsequent lines.
45   It has become possible to prevent the above mentioned reversal phenomenon by applying an auxiliary   45
signal is disclosed by Kanbe et al in GB-A 2141279. However, in a case where a ferroelectric liquid crystal causing an inversion between stable states at a shorter voltage application time with respect to a prescribed weak voltage, such an inversion can still occur. This is because when a certain signal electrode is supplied with a "white" information signal and a "black" information signal alternately in the multiplex driving, a pixel
50 after writing on the signal electrode is supplied with a voltage of one and same polarity for a period of $4\Delta t$ or   50
longer (Δt: a period for applying a writing voltage), whereby a written state of the pixel after writing (e.g., "white") can be inverted to the other written state (e.g., "black").

Summary of the invention
55   An object of the present invention is to provide a driving method for optical modulation device having   55
solved the problems encountered in the conventional liquid crystal display devices or optical shutters.
According to a first aspect of the present invention, there is provided a driving method for an optical modulation device comprising scanning electrodes and signal electrodes disposed opposite to and intersect-ing with the signal electrodes, and an optical modulation material disposed between the scanning electrodes
60 and the signal electrodes, a pixel being formed at each intersection of the scanning electrodes and the signal   60
electrodes and showing a contrast depending on the polarity of a voltage applied thereto; the driving method comprising, in a writing period for writing in all or prescribed pixels among the pixels on a selected scanning electrode among said scanning electrodes.
a first phase for applying a voltage of one polarity having an amplitude exceeding a first threshold voltage
65 of the optical modulation material to the all or prescribed pixels, and   65

a third phase for applying a voltage of the other polarity having an amplitude exceeding a second threshold voltage of the optical modulation material to a selected pixel and applying a voltage not exceeding the threshold voltages of the optical modulation material to the other pixels, respectively among the all or prescribed pixels,

5   a second phase not determining the contrast of the all or prescribed pixels being further disposed between the first and third phases.

According to a second aspect of the present invention, there is provided a driving method of an optical modulation device as described above, which driving method comprises, in a writing period for writing in all or prescribed pixels among the pixels on a selected scanning electrode among said scanning electrodes:

10   a first phase for applying a voltage of one polarity having an amplitude exceeding a first threshold voltage of the optical modulation material to a nonselected pixel among the all or prescribed pixels,

a second phase for applying a voltage of said one polarity having an amplitude exceeding the first threshold voltage to a selected pixel among said all or prescribed pixels, and

a third phase for applying a voltage of the other polarity having an amplitude exceeding a second threshold
15   voltage of the optical modulation material to the selected pixel.

According to a third aspect of the present invention, there is provided a driving method for an optical modulation device as described above, which comprises:

writing into all ore prescribed pixels on a selected scanning electrode among the scanning electrodes in a writing period including at least three phases, and

20   applying voltages of mutually opposite polarities at the first phase and the last phase among said at least three phases and each having an amplitude not exceeding the threshold voltages of said optical modulation material to the pixels on a nonselected scanning electrode.

According to a fourth aspect of the present invention, there is provided a driving method for an optical modulation device as described above, which comprises:

25   a first step of applying a voltage of one polarity exceeding a first threshold voltage of the optical modulation material to all or a prescribed number of the pixels arranged in a matrix, and

a second step including a second phase for applying a voltage of the other polarity exceeding a second threshold voltage of the optical modulation material to a selected pixel on a selected scanning electrode among the scanning electrodes so as to determine the contrast of the selected pixel, and a first phase for not
30   determining the contrast of the selected pixel disposed prior to the second phase.

These and other objects, features and advantages of the present invention will become more apparent upon a consideration of the following description of the preferred embodiments of the present invention taken in conjunction with the accompanying drawings.

35   *Brief description of the drawings*

Figure 1 shows threshold characteristic curves of ferroelectric liquid crystals;

Figures 2 and *3* are schematic perspective views for illustrating the operation principles of a ferroelectric liquid crystal device used in the present invention;

Figure 4 is a plan view of a matrix pixel arrangement used in the present invention;

40   *Figures 5A - 5D, Figures 8A - 8D, Figures 11A - 11D, Figures 14A - 14D, Figures 17A - 17D, Figures 20A - 20D,* and *Figures 23A - 23D* respectively show voltage waveforms of signals applied to electrodes;

Figures 6A - 6D, Figures 9A - 9D, Figures 12A - 12D, Figures 15A - 15D, Figures 18A - 18D, Figures 21A - 21D, and *Figures 24A - 24D* respectively show voltage waveforms of signals applied to pixels;

Figures 7, 10, 13, 16, 19, 22 and *25* show voltage waveforms of the above signals applied and expressed in
45   time series;

Figures 26A - 26C show voltage waveforms applied to electrodes in a whole area-clearing step; *Figures 27A - 27D* respectively voltage waveforms applied to electrodes in a writing step; *Figures 28A - 28D* are voltage waveforms applied to pixels in a writing step; *Figures 29* shows the above mentioned voltage signals in time series; and

50   *Figures 30A - 30D* show another set of voltage waveforms applied in a whole area-clearing step.

Description of the preferred embodiments

As an optical modulation material used in a driving method according to the present invention, a material showing at least two stable states, particularly one showing either a first optically stable state or a second
55   optically stable state depending upon an electric field applied thereto, i.e., bistability with respect to the applied electric field, particularly a liquid crystal having the above-mentioned property, may suitably be used.

Preferable liquid crystals having bistability which can be used in the driving method according to the present invention are chiral smectic liquid crystals having ferroelectricity. Among them, chiral smectic C
60   (SmC*)- or H (SmH*)-phase liquid crystals are suitable therefor. These ferroelectric liquid crystals are described in, e.g., "LE JOURNAL DE PHYSIQUE LETTRES" *36* (L-69), 1975 "Ferroelectric Liquid Crystals"; "Applied Physics Letters *36* (11) 1980, "Submicro Second Bistable Electrooptic Switching in Liquid Crystals", "Kotai Butsuri (Solid State-Physics)" *16* (141), 1981 "Liquid Crystal", etc. Ferroelectric liquid crystals disclosed in these publications may be used in the present invention.

65   More particularly, examples of ferroelectric liquid crystal compound used in the method according to the

present invention are decyloxybenzylidene-p'-amino-2-methylbutyl-cinnamate (DOBAMBC), hexyloxy-benzylidene-p'-amino-2-chloropropylcinnamate (HOBACPC), 4-o-(2-methyl)-butylresorcylidene-4'-octylaniline (MBRA8), etc.

When a device is constituted by using these materials, the device may be supported with a block of copper,
5 etc., in which a heater is embedded in order to realize a temperature condition where the liquid crystal
compounds assume an SmC*- or SmH*-phase.

Further, a ferroelectric liquid crystal formed in chiral smectic F phase, I phase, J phase, G phase or K phase may also be used in addition to those in SmC* or SmH* phase in the present invention.

Referring to Figure 2, there is schematically shown an example, of a ferroelectric liquid crystal cell. Refer-
10 ence numerals 21a and 21b denote substrates (glass plates) on which a transparent electrode of, e.g., In_2O_3,
SnO_2, ITO (Indium Tin Oxide), etc., is disposed, respectively. A liquid crystal of an SmC*-phase in which
liquid crystal molecular layers 22 are oriented perpendicular to surfaces of the glass plates is hermetically
disposed therebetween. A full line 23 shows liquid crystal molecules. Each liquid crystal molecule 23 has a
dipole moment $(P_\perp)$ 24 in a direction perpendicular to the axis thereof. When a voltage higher than a certain
15 threshold level is applied between electrodes formed on the substrates 21a and 21b, a helical structure of the
liquid crystal molecule 23 is unwound or released to change the alignment direction of respective liquid
crystal molecules 23 so that the dipole moments $(P_\perp)$ 24 are all directed in the direction of the electric field.
The liquid crystal molecules 23 have an elongated shape and show refractive anisotropy between the long
axis and the short axis thereof. Accordingly, it is easily understood that when, for instance, polarizers arran-
20 ged in a cross nicol relationship, i.e., with their polarizing directions being crossing each other are disposed
on the upper and the lower surfaces of the glass plates, the liquid crystal cell thus arranged functions as a
liquid crystal optical modulation device of which optical characteristics vary depending upon the polarity of
an applied voltage. Further, when the thickness of the liquid crystal cell is sufficiently thin (e.g., 1 μ), the
helical structure of the liquid crystal molecules is unwound without application of an electric field whereby
25 the dipole moment assumes either of the two states, i.e., Pa in an upper direction 34a or Pb in a lower
direction 34b as shown in Figure 3. When electric field Ea or Eb higher than a certain threshold level and
different from each other in polarity as shown in Figure 3 is applied to a cell having the above-mentioned
characteristics, the dipole moment is directed either in the upper direction 34a or in the lower direction 34b
depending on the vector of the electric field Ea or Eb. In correspondence with this, the liquid crystal mole-
30 cules are oriented to either of a first stable state 33a and a second stable state 33b.

When the above-mentioned ferroelectric liquid crystal is used as an optical modulation element, it is pos-
sible to obtain two advantages. First is that the response speed is quite fast. Second is that the orientation of
the liquid crystal shows bistability. The second advantage will be further explained, e.g., with reference to
Figure 3. When the electric field Ea is applied to the liquid crystal molecules, they are oriented to the first
35 stable state 33a. This state is stably retained even if the electric field is removed. On the other hand, when the
electric field Eb of which direction is opposite to that of the electric field Ea is applied thereto, the liquid crystal
molecules are oriented to the second stable state 33b, whereby the directions of molecules are changed.
Likewise, the latter state is stably retained – even if the electric field is removed. Further, as long as the
magnitude of the electric field Ea or Eb being applied is not above a certain threshold value, the liquid crystal
40 molecules are placed in the respective orientation states. In order to effectively realize high response speed
and bistability, it is preferable that the thickness of the cell is as thin as possible and generally 0.5 to 20 μ,
particularly 1 to 5 μ.

In a preferred embodiment according to the present invention, there is provided a liquid crystal device
comprising scanning electrodes which are sequentially and cyclically selected based on a scanning signal,
45 signal electrodes which are disposed opposite to the scanning electrodes and selected based on a prescribed
information signal, and a liquid crystal showing bistability in response to an electric field and disposed
between the two types of electrodes; and the liquid crystal device is driven by a method which comprises, in
the period of selecting a scanning electrode, a first phase t_1 and a second phase t_2 for applying a voltage in
one direction for orienting the liquid crystal to its second stable state (assumed to provide a "black" display
50 state), and a third phase t_3 for applying a voltage in the other direction for re-orienting the liquid crystal to a
first stable state (assumed to provide a "white" display state) depending on an electric signal applied to a
related signal electrode.

A preferred embodiment of the driving method according to the present invention will now be explained
with reference to Figures 4 and 7.
55 Referring to Figure 4, there is schematically shown an example of a cell 41 having a matrix electrode
arrangement in which a ferroelectric liquid crystal (not shown) is interposed between scanning electrodes 42
and signal electrodes 43. For brevity of an explanation, a case where binary states of "white" and "black" are
displayed will be explained. In Figure 4, the hatched pixels are assumed to be displayed in "black" and the
other pixels, in "white". Figures 5A and 5B show a scanning selection signal applied to a selected scanning
60 electrode and a scanning nonselection signal applied to the other scanning electrodes (nonselected scanning
electrodes), respectively. Figures 5C and 5D show an information selection signal applied to a selected signal
electrode and an information non-selection signal applied to a nonselected signal electrode. In Figures 5A -
5D, the abscissa and the ordinate represent time and voltage, respectively.

Figure 6A shows a voltage waveform applied to a pixel on a selected scanning electrode line and on a
65 selected signal electrode line, whereby the pixel is written in "white".

Figure 6B shows a voltage waveform applied to a pixel on a selected scanning electrode line and on a nonselected signal electrode line, whereby the pixel is written in "black".

Figure 6C shows a voltage waveform applied to a pixel on a nonselected scanning electrode line and on a selected signal electrode line, and Figure 6D shows a voltage waveform applied to a pixel on a non-selected
5   scanning electrode line and on a nonselected signal electrode line. Further, Figure 7 shows the above voltage   5
waveforms shown in time series.

According to the driving method of the present invention, during a writing period (phases $t_1 + t_2 + t_3$) for writing in the pixels on a selected scanning electrode line among the matrix pixel arrangement, all or a prescribed part of the pixels on the line are brought to one display state in at least one of the pahses t_1 and t_2,
10   and then only a selected pixel is inverted to the other display state, whereby one line is written. Such a writing   10
operation is sequentially repeated with respect to the scanning electrode lines to effect writing of one whole picture.

Now, if a first threshold voltage for providing a first stable state (assumed to provide a "white" state) of a bistable ferroelectric liquid crystal device for an application time of Δt (writing pulse duration) is denoted by
15    $-V_{th1}$, and a second threshold voltage for providing a second stable state (assumed to provide a "black"   15
state) for an application time Δt is denoted by $+V_{th2}$, an electric signal applied to a selected scanning electrode has voltage levels of $-2V_0$ at phase (time) t_1, $-2V_0$ at phase t_2 and $2V_0$ at phase t_3 as shown in Figure 5A. The other scanning electrodes are grounded and placed in a 0 volt state as shown in Figure 5B. On the other hand, an electric signal applied to a selected signal electrode has voltage levels of $-V_0$ at phase t_1, V_0 at phase
20   t_2 and again V_0 at phase t_3 as shown in Figure 5C. Further, an electric signal applied to a nonselected signal   20
electrode has voltage levels of V_0 at phase t_1, $-V_0$ at phase t_2 and V_0 at phase t_3.

In this way, both the voltage waveform applied to a selected signal electrode and the voltage waveform applied to a nonselected signal electrode, alternate corresponding to the phases t_1, t_2 and t_3, and the respective alternating waveforms have a phase difference of 180° from each other.
25   In the above, the respective voltage values are set to desired values satisfying the following relationships: 25

$$V_0 < V_{th2} < 3V_0, \text{ and}$$

$$-3V_0 < -V_{th1} < -V_0.$$
30   30

Voltage waveforms applied to respective pixels when the above electric signals are applied, are shown in Figures 6A - 6D.

As shown in Figure 6A, a pixel on a selected scanning electrode line and on a selected signal electrode line is supplied with a voltage of $3V_0$ exceeding the threshold V_{th2} at phase t_2 to assume a "black" display state
35   based on the second stable state of the ferroelectric liquid crystal, and then in the subsequent phase t_3, is   35
supplied with a voltage of $-3V_0$ exceeding the threshold $-V_{th1}$ to be written in a "white" display state based on the first stable state of the ferroelectric liquid crystal. Further, as shown in Figure 6B, a pixel on a selected scanning electrode line and on a nonselected signal electrode line is supplied with a voltage of $3V_0$ exceeding the threshold V_{th2} at phase t_1 to assume a "black" display state, and then in the subsequent phases t_2 and t_3, is
40   supplied with V_0 and $-V_0$ below the thresholds, so that the pixel is written in a black display state.   40

Figure 7 shows the above mentioned driving signals expressed in time series. Electric signals applied to scanning electrodes are shown at $S_1 - S_5$, electric signals applied to signal electrodes are shown at I_1 and I_3, and voltage waveforms applied to pixels A and C in Figure 4 are shown at A and C.

Now, the significance of the intermediate phase t_2 will now be explained in some detail. Microscopic
45   mechanism of switching due to electric field of a ferroelectric liquid crystal under bistability condition has not   45
been fully clarified. Generally speaking, however, the ferroelectric liquid crystal can retain its stable state semi-permanently, if it has been switched or oriented to the stable state by application of a strong electric field for a predetermined time and is left standing under absolutely no electric field. However, when a reverse polarity of an electric field is applied to the liquid crystal for a long period of time, even if the electric field is
50   such a weak field (corresponding to a voltage below V_{th} in the previous example) that the stable state of the   50
liquid crystal is not switched in a predetermined time for writing, the liquid crystal can change its stable state to the other one, whereby correct display or modulation of information cannot be accomplished. We have recognized that the liability of such switching or reversal of oriented states under a long term application of a weak electric field is affected by a material and roughness of a base plate contacting the liquid crystal and the
55   kind of the liquid crystal, but have not clarified the effects quantitatively. We have confirmed a tendency that a   55
uniaxial treatment of the substrate such as rubbing or oblique or tilt vapor deposition of SiO, etc., increases the liability of the above-mentioned reversal of oriented states. The tendency is manifested at a higher temperature compared to a lower temperature.

Anyway, in order to accomplish correct display or modulation of information, it is advisable that one
60   direction of electric field is prevented from being applied to the liquid crystal for a long time.   60
In view of the above problem, in the above embodiment of the driving method according to the present invention, the pixels on a nonselected scanning electrode line is only supplied with a voltage waveform alternating between $-V_0$ and V_0 both below the threshold voltages as shown in Figures 6C and 6D, so that the liquid crystal molecules therein do not change the orientation states but keep providing the display states
65   attained in the previous scanning. Further, as the voltages of V_0 and $-V_0$ are alternatively repeated in the   65

phases t_1, t_2 and t_3, the phenomenon of inversion to another stable state (i.e., crosstalk) due to continuous application of a voltage of one direction does not occur. Furthermore, in the present invention, the period wherein a voltage of V_0 (nonwriting voltage) is continually applied to a pixel A or C is $2\triangle T$ at the longest appearing at a waveportion 71 in the waveform shown at A, wherein $\triangle T$ denotes a unit writing pulse, and
5   each of the phases t_1, t_2 and t_3 has a pulse duration $\triangle T$ in this embodiment, so that the above mentioned   5
inversion phenomenon can be completely prevented even if the voltage margin during driving (i.e., difference between writing voltage level ($3V_0$) and nonwriting voltage level (V_0)) is not widely set. Further, in this embodiment, one pixel is written in a total pulse duration of $3\triangle T$ including the phases t_1, t_2 and t_3, so that writing of one whole picture can be written at a high speed.
10   As described above according to this embodiment, even when a display panel using a ferroelectric liquid   10
crystal device is driven at a high speed, the maximum pulse duration of a voltage waveform continually applied to the pixels on the scanning electrode lines to which a scanning nonselected signal is applied is suppressed to twice the writing pulse duration $\triangle T$, so that the phenomenon of one display state being inverted to another display state during writing of one picture frame may be effectively prevented.
15   Figures 8 - 10 show another embodiment of the driving method according to the present invention.   15
Figures 8A and 8B show a scanning selection signal applied to a selected scanning electrode and a scanning non-selection signal applied to the other scanning electrodes (nonselected scanning electrodes), respectively. Figures 8C and 8D show an information selection signal applied to a selected signal electrode and an information non-selection signal applied to a nonselected signal electrode. The information selection
20   signal and the information non-selection signal have mutually different waveforms, and have the same pol-   20
arity in a first phase t_1. In Figures 8A - 8D, the abscissa and the ordinate represent time and voltage, respectively. A writing period includes a first phase t_1, a second phase t_2 and a second phase t_3. In this embodiment, $t_1 = t_2 = t_3$. A writing period is sequentially provided to the scanning electrodes 42.
When $-V_{th1}$ and V_{th2} are defined as in the previous example, an electric signal applied to a selected scan-
25   ning electrode has voltage levels of $2V_0$ at phase (time) t_1 and phase t_2, and $-2V_0$ at phase t_3 as shown in   25
Figure 8A. The other scanning electrodes are grounded and placed in a 0 volt state as shown in Figure 8B. On the other hand, an electric signal applied to a selected signal electrode has voltage levels of $-V_0$ at phase t_1, and V_0 at phases t_2 and t_3 as shown in Figure 8C. Further, an electric signal applied to a nonselected signal electrode has voltage levels of $-V_0$ at phase t_1, V_0 at phase t_2 and $-V_0$ at phase t_3.
30   In the above, the respective voltage values are set to desired values satisfying the relationships of $V_0 < V_{th2}$ 30
$< 3V_0$, and $-3V_0 < -V_{th1} < -V_0$. Voltage waveforms applied to respective pixels when the above electric signals are applied, are shown in Figures 9A - 9D.
Figures 9A and 9B show voltage waveforms applied to pixels for displaying "black" and "white", respectively, on a selected scanning electrodes. Further, Figures 9C and 9D show voltage waveforms re-
35   spectively applied to pixels on nonselected scanning electrodes. As apparent in view of Figures 9A and 9B, all   35
or a prescribed part of the pixels on a selected scanning electrode is supplied with a voltage of $-3V_0$ exceeding the threshold voltage $-V_{th1}$ at a first phase t_1 to be once uniformly brought to "white". This phase is referred to as an erasure phase. Among these pixels, a pixel to be displayed in "black" is supplied with a voltage $3V_0$ exceeding the threshold voltage V_{th2}, so that it is inverted to the other optically stable state
40   ("black"). This is referred to as a display selection phase. Further, pixels for displaying "white" is supplied   40
with a voltage V_0 not exceeding the threshold voltage $-V_{th}$ at the third phase t_3, so that it remains in the one optically stable state (white).
On the other hand, all the pixels on a nonselected scanning electrode are supplied with a voltage of $\pm V_0$ or 0, each not exceeding the threshold voltages. As a result, the liquid crystal molecules therein do not change
45   their orientation states but retain orientation states corresponding to the display states resulted in the time of   45
last scanning. Thus, when a scanning electrode is selected, the pixels thereon are once uniformly brought to one optically stable state (white), and then at the third phase, selected pixels are shifted to the other optically stable state (black), whereby one line of signal states are written, which are retained until the line is selected next time.
50   Figure 10 shows the above mentioned driving signals expressed in time series. Electric signals applied to   50
scanning electrodes are shown at S_1 - S_5, electric signals applied to signal electrodes are shown at I_1 and I_3, and voltage waveforms applied to pixels A and C in Figure 4 are shown at A and C.
At the time of scanning in the driving method, the pixels on a scanning electrode concerned are once uniformly brought to "white" at a first phase t_1, and then at a third phase t_3, selected pixels are rewritten into
55   "black". In this embodiment, the voltage for providing "white" at the first phase t_1 is $-3V_0$, and the applica-   55
tion period thereof is $\triangle t$. On the other hand, the voltage for rewriting into "black" is $3V_0$, and the application period thereof is $\triangle t$. Further, the voltage applied to the pixels at time other than the time of scanning is $|\pm V_0|$ at the maximum. The longest period wherein the voltage is continuously applied is $2\triangle t$ as appearing at 101 shown in Figure 10, because a second phase, i.e., an auxiliary phase (auxiliary signal application phase) for
60   applying an auxiliary signal not determining a display state of a pixel, is provided. As a result, the above   60
mentioned crosstalk phenomenon does not occur at all, and when scanning of one whole picture frame is once completed, the displayed information is semipermanently retained, so that a refreshing step as required for a display device using a conventional TN liquid crystal having no bistability is not required at all. Furthermore, according to this embodiment, the period wherein a particular voltage is applied is $2\triangle t$ at the
65   maximum, so that the driving voltage margin can be flexibly set without causing an inversion phenomenon.   65

As may be understood from the above description, the term "display (contrast) selection phase" or "display (contrast) determining phase" used herein means a phase which determines one display state of a selected pixel, bright state or dark state and which is the last phase wherein a voltage having an amplitude exceeding a threshold voltage of a ferroelectric liquid crystal is applied, during a writing period for the pixels on a selected scanning line. More specifically, in the embodiment of Figure 8, the phase t_3 is a phase wherein a black display state, for example, is determined with respect to a selected pixel among the respective pixels on a scanning electrode line, and corresponds to a "display state selection phase".

Further, the term "auxiliary phase" described herein means a phase for applying an auxiliary signal not determining the display state of a pixel and a phase other than the display state selection phase and the erasure phase. More specifically, the phase t_2 in Figure 8 corresponds to the auxiliary phase.

Example 1

On each of a pair of glass plates provided thereon with transparent conductor films patterned so as to provide a matrix of 500×500 intersections, an about 300 Å-thick polyimide film was formed by spinner coating. The respective substrates were treated by rubbing with a roller about which a cotton cloth was wound and superposed with each other so that their rubbing directions coincided with each other to form a cell with a spacing of about 1.6 μ. Into this cell was injected a ferroelectric liquid crystal DOBAMBC (decyloxybenzylidene-p'-amino-2-methyl-butylcinnamate) under heating, which was then gradually cooled to form a uniform monodomain of SmC* phase. The cell was controlled at a temperature of 70°C and subjected to a line sequential driving method as explained with reference to Figures 8 - 10 wherein the respective values were set to $V_0 = 10$ volts, and $t_1 = t_2 = t_3 = \Delta t = 50$ μsec., whereby a very good image was obtained.

A driving embodiment further improved over the above described embodiment is explained with reference to Figures 11 - 13.

Figures 11A and 11B show a scanning selection signal applied to a selected scanning electrode and a scanning non-selection signal applied to the other scanning electrodes (nonselected scanning electrodes), respectively. Phases t_1 and t_3 correspond to the above mentioned erasure phase and display state selection phase, respectively. Phase t_2 is an auxiliary phase (auxiliary signal application phase). These are the same as used in the previous driving embodiment. In this driving embodiment, an additional auxiliary phase not determining the display state of a pixel is provided as a fourth phase t_4. In the fourth phase t_4, a voltage of 0 volt is applied to all the scanning electrode lines, and the signal electrodes are supplied with a voltage of $\pm V_0$ having a polarity opposite to the voltage applied at the third phase t_3.

The voltage applied to the respective pixels at the time of non-selection is $|\pm V_0|$ at the maximum, and the longest period for which the voltage $\pm V_0$ is applied is $2\Delta t$ at a part $|3|$ shown in Figure 13 because of the application of the auxiliary signals at phases t_2 and t_4. Furthermore, the frequency of the occurrence of such $2\Delta t$ period is small, and the voltage applied for the Δt period alternates to weaken the voltage applied to the respective pixels at the time of non-selection, so that no crosstalk occurs at all. Then, when scanning of one whole picture is once completed, the displayed information is semipermanently retained, so that a refreshing step as required for a display device using a conventional TN liquid crystal having no bistability is not required at all.

Further, in the present invention, it is possible that the above mentioned phase t_4 is placed before the phase t_1.

Figures 14 - 16 show another embodiment of the present invention. Figures 14A and 14B show a scanning selection signal applied to a selected scanning electrode and a scanning non-selection signal applied to the other scanning electrodes (nonselected scanning electrodes), respectively. Phases t_1 and t_3 correspond to the erasure phase and display state selection phase, respectively. Phases t_2 and t_4 are auxiliary phases for applying an auxiliary signal not determining a display state.

A scanning selectional applied to a selected scanning electrode has a voltage waveform showing $3V_0$ at phase t_1, 0 at phase t_2, $-2V_0$ at phase t_3, and 0 at phase t_4 as shown in Figure 14A. The other scanning electrodes are grounded as shown in Figure 14B and the applied electric signal is 0. On the other hand, a selected signal electrode is supplied with an information selection signal as shown in Figure 14C, which shows 0 at phase t_1, $-V_0$ at phase t_2, $+V_0$ at phase t_3, and $-V_0$ at phase t_4. Further, a non-selected signal electrode is supplied with an information nonselection signal as shown in Figure 14D, which shows 0 at phase t_1, $+V_0$ at phase t_2, $-V_0$ at phase t_3 and $+V_0$ at phase t_4. The lengths of the respective phases are set to satisfy $t_1 = t_3$, $t_2 = t_4$, and $1/2.t_1 = t_2$. In the above, the voltage value V_0 is set in the same manner as in the previous examples. Figure 15 shows voltage waveforms applied to respective pixels, when such electric signals are applied.

Figures 15A and 15B show voltage waveforms applied to pixels for displaying "black" and "white", respectively, on a selected scanning electrode. Further, Figures 15C and 15D show voltage waveforms respectively applied to pixels on nonselected scanning electrodes. All or a prescribed part of the pixels are once uniformly brought to "white" at a first phase t_1 as in the previous examples. Among these, a pixel for displaying "black" is brought to "black" based on the other optically stable state at a third phase t_3. Further, on the same scanning electrode, a pixel for displaying "white" is supplied with a voltage of V_0 not exceeding the threshold voltage V_{th1} at the phase t_3, so that it remains in one optically stable state.

On the other hand, on the nonselected scanning electrode, all the pixels are supplied with a voltage of $\pm V_0$ or 0 not exceeding the threshold voltages, as in the previous examples. As a result, the liquid crystal mole-

cules therein do not change their orientation states but retain orientation states corresponding to the display
states resulted in the time of last scanning. Thus, when a scanning electrode is selected, the pixels thereon
are once uniformly brought to one optically stable state (white), and then at the third phase, selected pixels
are shifted to the other optically stable state (black), whereby one line of signal states are written, which are
5 retained until the line is selected next time.
     Figure 16 shows the above mentioned driving signals expressed in time series. Electric signals applied to
scanning electrodes are shown at S_1 - S_5, electric signals applied to signal electrodes are shown at I_1 and I_3,
and voltage waveforms applied to pixels A and C in Figure 4 are shown at A and C.
     In this embodiment, the voltage for providing "white" at the first phase t_1 is $-3V_0$, and the application
10 period thereof is $\triangle t$. On the other hand, the voltage for rewriting into "black" is again $3V_0$, and the application
period thereof is $\triangle t$. Further, the voltage applied to the pixels at time other than the time of scanning is $|\pm V_0|$ at
the maximum. The longest period wherein the voltage is continuously applied is $2.5\triangle t$ even when white-
white signals are continued, because of the auxiliary signals applied at the phases t_2 and t_4. Further, a smaller
weak voltage is applied to the respective pixels, so that no crosstalk occurs at all, and when the scanning of
15 one whole picture frame is once completed, the resultant displayed information is retained semiperman-
ently.
     Figures 17 - 19 show another driving embodiment according to the present invention. Figure 17A shows a
scanning selection signal applied to a selected scanning electrode line, which shows $2V_0$ at phase t_1, 0 at
phase t_2, and $-2V_0$ at phase t_3. Figure 17B shows a scanning non-selection signal applied to a nonselected
20 scanning electrode line, which is 0 over the phases t_1, t_2 and t_3. Figure 17C shows an information selection
signal applied to a selected signal electrode, which shows $-V_0$ at phase t_1, and V_0 at phases t_2 and t_3. Figure
17D shows an information non-selection signal applied to a nonselected signal electrode, which has a wave-
form alternately showing $-V_0$ at phase t_1, V_0 at phase t_2, and $-V_0$ at phase t_3.
     Figure 18A shows a voltage waveform applied to a pixel when the above mentioned scanning selection
25 signal and information selection signal are applied in phase with each other. Figure 18B shows a voltage
waveform applied to a pixel when the scanning selection signal and the information non-selection signal are
applied in phase.
     Figure 18C shows a voltage waveform applied to a pixel when the above mentioned scanning non-
selection signal and information selection signal are applied, and Figure 18D shows a voltage waveform
30 applied to a pixel when the scanning non-selection signal and the information non-selection signal are app-
lied.
     Figure 19 shows the above mentioned driving signals expressed in time series, and voltage waveforms
applied to pixels A and C in Figure 4 are shown at A and C.
     As will be understood from Figure 19, the longest period for which a voltage is applied to a pixel at the time
35 of scanning non-selection is suppressed to $2\triangle t$.
     According to the previously described embodiments, even when a display panel using a ferroelectric liquid
crystal device is driven at a high speed, the maximum pulse duration of a voltage waveform continually
applied to the pixels on the scanning electrode lines to which a scanning nonselection signal is applied is
suppressed to two or 2.5 times the writing pulse duration $\triangle t$, so that the phenomenon of one display state
40 being inverted to another display state during writing of one whole picture may be effectively prevented.
     Figures 20 - 22 show another preferred embodiment of the driving method according to the present inven-
tion.
     Figures 20A and 20B show a scanning selection signal applied to a selected scanning electrode S and a
scanning non-selection signal applied to the other non-selected scanning electrodes, respectively. Figures
45 20C and 20D show an information selection signal (assumed to provide "black") applied to a selected signal
electrode and an information non-selection signal (assumed to provide "white") applied to a nonselected
signal electrode. In Figures 20A - 20D, the abscissa and the ordinate represent time and voltage, respectively.
In this embodiment, the lengths of the respective phases are set to satisfy $t_1 = t_2 = t_3$, and writing is effected
during the total period T $(= t_1 + t_2 + t_3)$. The writing period is sequentially allotted to the scanning electrodes
50 42.
     When the first threshold voltage $-V_{th1}$ and the second threshold voltage V_{th2} are defined in the previous
embodiments, an electric signal applied to a selected scanning electrode has voltage levels of $2V_0$ at phase
(time) t_1, $-2V_0$ at phase t_2 and 0 at phase t_3 as shown in Figure 20A. The other scanning electrodes are
grounded and the electric signal is 0 as shown in Figure 20B. On the other hand, an electric signal applied to a
55 selected signal electrode has voltage levels of $-V_0$ at phase t_1, V_0 at phase t_2 and again V_0 at phase t_3 as shown
in Figure 5C. Further, an electric signal applied to a nonselected signal electrode has voltage levels of $-V_0$ at
phase t_1, $-V_0$ at phase t_2 and V_0 at phase t_3. In the above, the voltage value V_0 is set to a desired value
satisfying the relationships of $V_0 < V_{th2} < 3V_0$ and $-V_0 > -V_{th1} > -3V_0$.
     Voltage waveforms applied to respective pixels when the above electric signals are applied, are shown in
60 Figures 21A - 21D. Figures 21A and 21B show voltage waveforms applied to pixels for displaying "black" and
"white", respectively, on a selected scanning electrode, and Figures 21C and 21D show voltage waveforms
respectively applied to pixels on a nonselected scanning electrode. As shown in Figures 21A - 21D, all the
pixels on a selected scanning electrode are first supplied with a voltae $-3V_0$ exceeding the threshold voltage
$-V_{th1}$ at a first phase t_1 to be once uniformly brought to "white". Thus, the phase t_1 corresponds to a line
65 erasure phase. Among these, a pixel for displaying "black" is supplied with a voltage $3V_0$ exceeding the

threshold voltage V_{th2} at a second phase t_2, so that it is converted to the other optically stable state ("black").
Further, a pixel for displaying "white" on the same scanning line is supplied with a voltage V_0 not exceeding
the threshold voltage V_{th2}, so that it remains in the one optically stable state.

On the other hand, all the pixels on the non-selected scanning electrodes are supplied with a voltage of $\pm V_0$
5 or 0, each not exceeding the threshold voltages, so that the liquid crystal molecules therein retain the orienta-   5
tion states corresponding to the signal states resulted in the previous scanning time. Thus, when a scanning
electrode is selected, the pixels thereon are once uniformly brought to one optically stable state (white), and
then at the next second phase, selected pixels are shifted to the other optically stable state (black), whereby
one line of signal states are written, which are retained until the line is selected after one frame of writing is   10
10 completed.

The third phase t_3 in this embodiment is a phase for preventing one direction of weak electric field from
being continuously applied. As a preferred example thereof, a signal having a polarity opposite to that of an
information signal applied to the signal electrodes at the phase t_3. For example, in a case where a pattern as
shown in Figure 4 is to be displayed, when a driving method having none of such a phase t_3 is applied, a pixel   15
15 A is written in "black" when a scanning electrodes S_1 is scanned, whereas during the scanning of the scan-
ning electrodes S_2 et seq., an electric signal of $-V_0$ is continually applied to the signal electrode I_1, and the
voltage is applied to the pixel A as it is. As a result, it is highly possible that the pixel a is inverted into "white"
before long.

At the time of scanning in the driving method, the pixels on a nonselected scanning electrode are once   20
20 uniformly brought to "white" at a first phase t_1, and then at a second phase t_2, selected pixels are rewritten
into "black". In this embodiment, the voltage for providing "white" at the first phase t_1 is $-3V_0$, and the
application period thereof is $\triangle t$. On the other hand, the voltage for rewriting into "black" is $3V_0$, and the
application period thereof is $\triangle t$. Further, the voltage V_0 is applied at the phase t_3 for a period of $\triangle t$. The
voltage applied to the pixels at time other than the time of scanning is $|\pm V_0|$ at the maximum. The longest   25
25 period wherein the voltage is continuously applied is $2\triangle t$ as appearing at 221 shown in Figure 22. As a result,
the above mentioned crosstalk phenomenon does not occur at all, and when scanning of one whole picture
frame is once completed, the displayed information is semipermanently retained, so that a refreshing step as
required for a display device using a conventional TN liquid crystal having no bistability is not required at all.

Particularly in this embodiment, the direction of a voltage applied to the liquid crystal layer in the first   30
30 phase t_1 is made on the $\ominus$ side even at the time of non-scanning selection regardless of whether the informa-
tion signal is for displaying "black" or "white", and the voltage at the final phase (the third phase t_3 in this
embodiment) is all made $+V_0$ on the $\oplus$ side, whereby the period for applying one continuous voltage which
can cause the above mentioned crosstalk phenomenon is suppressed to $2\triangle t$ or shorter. Further, the voltage
applied to a signal electrode at the third phase t_3 has a polarity opposite to that of the first phase and the same   35
35 polarity as that of the voltage at the second phase t_2 for writing "black". Therefore, the writing of "black" has
an effect of making sure of the prevention of crosstalk by the combination of $3V_0$ for $\triangle t$ and V_0 for $\triangle t$.

The optimum duration of the third phase t_3 depends on the magnitude of a voltage applied to a signal
electrode in this phase, and when the voltage has a polarity opposite to the voltage applied at the second
phase t_2 as an information signal, it is generally preferred that the duration is shorter as the voltage is larger   40
40 and the duration is longer as the voltage is smaller. However, if the duration is longer, a longer period is
required for scanning one whole picture area. For this reason, the duration is preferably set to satisfy $t_3 \leqq t_2$.

Example 2
A cell prepared in the same manner as in Example 1 was controlled at a temperature of 70°C and subjected
45 to a line sequential driving method as explained with reference to Figures 20 - 23, wherein the respective   45
values were set to V_0 = 10 volts, $t_1 = t_2 = t_3 = \triangle t = 50$ μsec., whereby a very good image was obtained.

Figures 23 - 25 shows another driving embodiment according to the present invention. Figure 23A shows a
scanning selection signal applied to a selected scanning electrode line, which shows $2V_0$ at phase t_1, $-2V_0$ at
phase t_2, V_0 at phase t_3, and 0 at phase t_4. Figure 23B shows a scanning non-selection signal applied to a   50
50 nonselected scanning electrode, which shows 0 over the phases t_1, t_2, t_3 and t_4. Figure 23C shows an informa-
tion selection signal applied to a selected signal electrode, which shows $-V_0$ at phase t_1, V_0 at phase t_2, 0 at
phase t_3, and V_0 at phase t_4. Figure 23D shows an information nonselection signal applied to a nonselected
signal electrode, which shows $-V_0$ at phases t_1 and t_2, 0 at phase t_3, and V_0 at phase t_4.

Figure 24A shows a voltage waveform applied to a pixel when the above mentioned scanning selection   55
55 signal and information selection signal are applied in phase with each other. Figure 24B shows a voltage
waveform applied to a pixel when the scanning selection signal and the information non-selection signal are
applied in phase. Figure 24C shows a voltage waveform applied to a pixel when the above mentioned scan-
ning non-selection signal and information selection signal are applied, and Figure 24D shows a voltage
waveform applied to a pixel when the scanning nonselection signal and the information non-selection signal   60
60 are applied. Writing is effected in a period T (= phases $t_1 + t_2 + t_3 + t_4$).

Figure 25 shows the above mentioned driving signals expressed in time series, and voltage waveforms
applied to pixels A and C in Figure 4 are shown at A and C.

Also in this embodiment, the voltages applied at the first phase t_1 and at the last phase t_4 are set to be of
mutually reverse polarities regardless of whether they are for selection or non-selection (or writing or non-   65
65 writing), whereby the above mentioned period which can cause crosstalk is suppressed to $2\triangle t$ at the longest.

In the above described embodiment, a writing period for one line is divided into 3 or 4 phases. In order to effect a high speed and efficient driving, the number of division should desirably be limted to about 5.

Figures 26 - 29 show another embodiment of the driving method according to the present invention, wherein a whole area-clearing step is provided.

5   Figures 26A - 26C show electric signals for uniformly bringing a picture area to "white" (referred to as "whole area – clearing signal") applied prior to writing in a whole area – clearing step T. More specifically, Figure 26A shows a voltage waveform $2V_0$ applied at a time or as a scanning signal to all or a prescribed part of the scanning electrodes 42. Figure 26B shows a voltage waveform $-V_0$ applied to all or a prescribed part of the signal electrodes 43 in phase with the signal applied to the scanning electrodes. Further, Figure 26C

10   shows a voltage waveform $-3V_0$ applied to the pixels. The whole area – clearing signal $-3V_0$ has a voltage level exceeding the threshold voltage $-V_{th1}$ of a ferroelectric liquid crystal and is applied to all or a prescribed part of the pixels, whereby the ferroelectric liquid crystal at such pixels is oriented to one stable state (first stable state) to uniformly bring the display state of the pixels to, e.g., a "white" display state. Thus, in the step T, the whole picture area is brought to the "white" state at one time or sequentially.

15   Figures 27A and 27B show an electric signal applied to a selected scanning electrode and an electric signal applied to the other scanning electrodes (nonselected scanning electrodes), respectively, in a subsequent writing step. Figures 27C and 27D show an electric signal applied to a selected signal electrode (assumed to provide "black") and an electric signal applied to a nonselected signal electrode (assumed to provide "white"), respectively. As in the preceding embodiments, in Figures 26 - 28, the abscissa and the ordinate

20   represent time and voltage respectively. In Figures 27A - 27D, t_2 and t_1 denote a phase for applying an information signal (and scanning signal) and a phase for applying an auxiliary signal, respectively. Figures 27A - 27D show an example of $t_1 = t_2 = \triangle t$.

The scanning electrodes are successively supplied with a scanning signal. Now, the threshold voltages $-V_{th1}$ and V_{th2} are defined as in the first embodiment. Then, the electric signal applied to a selected scanning

25   electrode has voltage levels of $2V_0$ at phase t_1 and $-2V_0$ at phase t_2 as shown in Figure 27A. The other scanning electrodes are grounded so that the electric signal is 0 as shown in Figure 27B. On the other hand, the electric signal applied to a selected signal electrode has voltage levels of $-V_0$ at phase t_1 and V_0 at phase t_2 as shown in Figure 27C. Further, the electric signal applied to a nonselected signal electrode has voltage levels of V_0 at phase t_1 and $-V_0$ at phase t_2 as shown in Figure 27D. In the above, the voltage value V_0 is set to a

30   desired value satisfying the relationships of $V_0 < V_{th2} < 3V_0$ and $-V_0 > -V_{th1} > -3V_0$.

Voltage waveforms applied to respective pixels when the above electric signals are applied, are shown in Figures 28A - 28D.

Figures 28A and 28B show voltage waveforms applied to pixels for displaying "black" and "white", respectively, on a selected scanning electrode. Figures 28C and 28D respectively show voltage waveforms

35   applied to pixels on a nonselected scanning electrode.

As shown in Figure 28A, a pixel on a selected scanning electrode and on a selected signal electrode, i.e., a pixel for displaying "black", is supplied with a voltage $-3V_0$ as shown in Figure 28A, which is the sum $|3V_0|$ of the absolute value of the voltage applied to the scanning line (Figure 27A) $|2V_0|$ and the absolute value of the voltage applied to the signal line (Figure 27C) $|V_0|$, respectively at phase t_1, and has a polarity on the side for

40   providing the first stable state. The pixel supplied with $-3V_0$ at phase t_1, which has been already brought to the first stable state by application of the whole area – clearing signal, retains the "white" state formed in the whole area – clearing step. Further, a pixel on a non-selected signal electrode is supplied with a voltage of $-V_0$ at phase t_1 as shown in Figure 28B, but does not change the white state preliminary formed in the whole area – clearing step as the voltage $-V_0$ is set to below the threshold voltage.

45   At phase t_2, the pixel on a selected scanning line and on a selected signal electrode is supplied with $3V_0$ as shown in Figure 28A. As a result, the selected pixel is supplied with a voltage of $3V_0$ exceeding the threshold voltage V_{th2} for the second stable state of the ferroelectric liquid crystal at phase t_2, so that it is transferred to a display state based on the second stable state, i.e., the black state. On the other hand, the pixel on a nonselected electrode is supplied with a voltage of $+V_0$ at phase t_2 as shown in Figure 28B, but retains the display state

50   formed at the phase t_1 as it is as the voltage $+V_0$ is set below the threshold voltage. Thus, the phase t_2 is a phase for determining the display states of the selected pixel on the scanning electrode, i.e., a display state (contrast) – determining phase with respect to the selected pixel. On the other hand, at the above mentioned phase t_1, no pixels on the scanning electrodes are supplied with a voltage exceeding the second threshold voltage, so that the phase t_1 may be referred to as an auxiliary phase in which the display state formed in the

55   above mentioned whole area – clearing step T is not changed, and the signal applied to the signal electrodes may be referred to as an auxiliary signal.

Figure 29 shows the above mentioned driving signals expressed in time series. Electric signals applied to scanning electrodes are shown at $S_1 - S_5$, electric signals applied to signal electrodes are shown at I_1 and I_3, and voltage waveforms applied to pixels A and C in Figure 4 are shown at A and C.

60   In this embodiment, the phase t_1 is a phase provided for preventing a weak electric field of one direction from being continually applied. In a preferred embodiment as shown in Figures 27C and 27D, signals having polarities respectively opposite to those of the information signals (for providing "black" in Figure 27C and "white" in Figure 27D) are applied at phase t_1 to the signal electrodes. For example, in a case where a pattern as shown in Figure 4 is to be displayed, when a driving method using none of such a phase t_1 is applied, a

65   pixel A is written in "black" when a scanning electrode S_1 is selected, whereas during the selection of the

scanning electrodes S_2, et seq., an electric signal of $-V_0$ is continually applied to the signal electrode I_1, and the voltage is applied to the pixel A as it is. As a result, it is highly possible that the pixel A is inverted into "white" before long. In this embodiment, as described above, all the pixels of at least a prescribed part of the pixels on the whole picture area is once uniformly brought to "white", and a pixel for displaying "black" is
5   once supplied with a voltage of $-3V_0$ at phase t_1 (but its display state is not determined at this phase) and is supplied with a voltage $3V_0$ for writing "black" in the subsequent phase t_2.

The duration of the phase t_2 for writing is $\triangle t$, and a voltage of $|+V_0|$ is applied at phase t_2 for retaining "white" for a period of $\triangle t$. Further, even at time other than scanning, the respective pixels supplied with a voltage of $|\pm V_0|$ at the maximum and the voltage $|\pm V_0|$ is not continually applied for longer than $2\triangle t$ except for
10   the writing period no matter what display states are continued. As a result, no crosstalk phenomenon occurs at all, and when scanning of one whole picture area is once completed, the displayed information is semi-permanently retained, so that a refreshing step as required for a display device using a conventional TN liquid crystal having no bistability is not required at all.

Figures 30A - 30C show another embodiment of whole area – clearing signals. Figure 30A shows a voltage
15   waveform applied to the scanning lines, which shows $-2V_0$ at phase P_1 and $2V_0$ at phase P_2. Figure 30B shows a voltage waveform applied to the signal electrodes, which shows V_0 at phase t_1 and $-V_0$ at phase t_2. Figure 30C shows a voltage waveform applied to the pixels, which shows $3V_0$ at phase P_1 and $-3V_0$ at phase P_2, whereby the pixels are once made "black" at phase P_1 but is written in a "white" state at phase P_2. In this way, all the pixels are supplied with an average voltage of 0, whereby the possibility of causing the above men-
20   tioned crosstalk is further decreased.

As described hereinabove, according to the present invention, even when a display panel using a fer-roelectric liquid crystal device is driven at a high speed, the maximum pulse duration of a voltage waveform continually applied to the pixels on the scanning electrode lines to which a scanning nonselection signal is applied is suppressed to two (or 2.5) times the writing pulse duration $\triangle t$, so that the phenomenon of one
25   display state being inverted to another display state during writing of one whole picture may be effectively prevented.

CLAIMS

30   1. A driving method for an optical modulation device comprising scanning electrodes and signal electro-des disposed opposite to and intersecting with the signal electrodes, and an optical modulation material disposed between the scanning electrodes and the signal electrodes, a pixel being formed at each intersec-tion of the scanning electrodes and the signal electrodes and showing a contrast depending on the polarity of a voltage applied thereto; said driving method comprising, in a writing period for writing in all or prescribed
35   pixels among the pixels on a selected scanning electrode among said scanning electrodes:

a first phase for applying a voltage of one polarity having an amplitude exceeding a first threshold voltage of the optical modulation material to said all or prescribed pixels, and

a third phase for applying a voltage of the other polarity having an amplitude exceeding a second threshold voltage of the optical modulation material to a selected pixel and applying a voltage not exceeding the
40   threshold voltages of the optical modulation material to the other pixels, respectively among said all or prescribed pixels,

a second phase not determining the contrast of said all or prescribed pixels being further disposed be-tween the first and third phases.

2. A driving method according to Claim 1, wherein a voltage having an amplitude not exceeding the
45   threshold voltages of the optical modulation material is applied to said all or prescribed pixels at the second phase.

3. A driving method according to Claim 1, wherein said first phase is disposed in a former half and said second phase is disposed in a latter half of said writing period.

4. A driving method according to Claim 1, wherein in the third phase, the voltage applied to the selected
50   pixels among said all or prescribed pixels has the same polarity as the voltage applied to said the other pixels.

5. A driving method according to Claim 1, wherein said selected scanning electrode is supplied with voltage signals of the same polarity at the first and second phases with respect to the potential of a nonselec-ted scanning electrode as a reference, and said the same polarity is opposite to the polarity of a voltage signal applied to the selected signal at the third phase with respect to the potential of the nonselected electrode.

55   6. A driving method according to Claim 1, wherein the duration of a continually applied voltage of the same polarity applied to a pixel on a scanning electrode among the scanning electrodes is two times the duration of the first phase at the maximum.

7. A driving method according to Claim 1, wherein said writing period further comprises a fourth phase not determining the contrast of said all or prescribed pixels, prior to the first phase or after the third phase.

60   8. A driving method according to Claim 7, wherein in the fourth phase, the selected scanning electrode is supplied with a voltage signal of 0 with respect to the potential of a nonselected scanning electrode.

9. A driving method according to Claim 1, wherein said writing period further comprises a fourth period not determining the contrast of said all or prescribed pixels, a voltage signal applied to the selected scanning electrode at the first phase and a voltage signal applied to the selected scanning electrode at the third phase
65   have the same polarity with respect to the potential of a nonselected scanning electrode, and voltage signals

applied to the selected scanning electrode at the second and fourth phases have the same polarity with respect to the potential of the non-selected scanning electrode.

10. A driving method according to Claim 9, wherein said first, second, third and fourth phases have durations of t_1, t_2, t_3 and t_4, respectively, satisfying the relationships of $t_1 = t_3$, $t_2 = t_4$ and $1/2 \cdot t_1 = t_2$.

11. A driving method according to Claim 1, wherein a voltage signal applied to the selected scanning electrode at the first phase and a voltage signal applied to the selected scanning electrode at the third phase have the same polarity with respect to the potential of a nonselected scanning electrode, and a voltage signal applied to the selected scanning electrode at the second phase has a voltage of 0 with respect to the potential of a nonselected scanning electrode.

12. A driving method according to Claim 1, wherein a scanning selection signal for defining a selected scanning electrode is sequentially applied to the scanning electrodes, and the sequential application of the scanning selection signal is cyclically repeated.

13. A driving method according to Claim 1, wherein said optical modulation material comprises a ferroelectric liquid crystal.

14. A driving method according to Claim 13, wherein said ferroelectric liquid crystal comprises a chiral smectic liquid crystal.

15. A driving method according to Claim 14, wherein said chiral smectic liquid crystal is disposed in a layer thin enough to release the helical structure of the chiral smectic liquid crystal in the absence of an electric field.

16. A driving method for an optical modulation device comprising scanning electrodes and signal electrodes disposed opposite to and intersecting with the signal electrodes, and an optical modulation material disposed between the scanning electrodes and the signal electrodes, a pixel being formed at each intersection of the scanning electrodes and the signal electrodes and showing a contrast depending on the polarity of a voltage applied thereto; said driving method comprising, in a writing period for writing in all or prescribed pixels among the pixels on a selected scanning electrode among said scanning electrodes:

a first phase for applying a voltage of one polarity having an amplitude exceeding a first threshold voltage of the optical modulation material to a nonselected pixel among said or prescribed pixels,

a second phase for applying a voltage of said one polarity having an amplitude exceeding the first threshold voltage to a selected pixel among said all or prescribed pixels, and

a third phase for applying a voltage of the other polarity having an amplitude exceeding a second threshold voltage of the optical modulation material to the selected pixel.

17. A driving method according to Claim 16, wherein a voltage having an amplitude not exceeding the threshold voltages of the optical modulation material is applied to said all or prescribed pixels at the third phase.

18. A driving method according to Claim 16, wherein said second phase is disposed subsequent to said first phase.

19. A driving method according to Claim 16, wherein the duration of a continually applied voltage of the same polarity applied to a pixel on a scanning electrode among the scanning electrodes is two times the duration of the first phase at the maximum.

20. A driving method according to Claim 16, wherein said selected scanning electrode is supplied with voltage signals of the same polarity at the first and second phases with respect to the potential of a nonselected scanning electrode, and said the same polarity is opposite to the polarity of a voltage signal applied to the selected scanning at the third phase with respect to the potential of the nonselected electrode.

21. A driving method according to Claim 16, wherein the pixels on a nonselected scanning electrode among the scanning electrodes is supplied with voltages of the same polarity at the first and third phases and with a voltage of a polarity opposite to said the same polarity.

22. A driving method according to Claim 21, wherein among the pixels on a nonselected scanning electrode, a pixel on a selected signal electrode is supplied with a voltage of a polarity opposite to that of a voltage applied to a pixel on a nonselected signal electrode, respectively at the first, second and third phases.

23. A driving method according to Claim 16, wherein a scanning selection signal for defining a selected scanning electrode is sequentially applied to the scanning electrodes, and the sequential application of the scanning selection signal is cyclically repeated.

24. A driving method according to Claim 16, wherein said optical modulation material comprises a ferroelectric liquid crystal.

25. A driving method according to Claim 24, wherein said ferroelectric liquid crystal comprises a chiral smectic liquid crystal.

26. A driving method according to Claim 25, wherein said chiral smectic liquid crystal is disposed in a layer thin enough to release the helical structure of the chiral smectic liquid crystal in the absence of an electric field.

27. A driving method for an optical modulation device comprising scanning electrodes and signal electrodes disposed opposite to and intersecting with the signal electrodes, and an optical modulation material disposed between the scanning electrodes and the signal electrodes, a pixel being formed at each intersection of the scanning electrodes and the signal electrodes and showing a contrast depending on the polarity of a voltage applied thereto; said driving method comprising:

writing into all or prescribed pixels on a selected scanning electrode among the scanning electrodes in a

writing period including at least three phases, and

applying voltages of mutually opposite polarities at the first phase and the last phase among said at least three phases and each having an amplitude not exceeding the threshold voltages of said optical modulation material to the pixels on a nonselected scanning electrode.

5   28.   A driving method according to Claim 27, wherein a voltage of one polarity exceeding a first threshold   5
voltage of the optical modulation material is applied to said all or prescribed pixels at at least one phase among said at least three phases, and a voltage of the other polarity exceeding a second threshold voltage of the optical modulation material is applied to a selected pixel among said all or prescribed pixels at another at least one phase.

10   29.   A driving method according to Claim 27, wherein said selected scanning electrode is supplied with   10
two voltage signals of mutually opposite polarities, and a voltage signal of 0, respectively with respect to the potential of a nonselected scanning electrode, in the writing period including said at least three phases, and said voltage signal of 0 is applied in the last phase among said at least three phases.

30.   A driving method according to Claim 29, wherein said two voltage signals have the same amplitude.

15   31.   A driving method according to Claim 27, wherein said selected scanning electrode is supplied with   15
two voltage signals having the same amplitude of mutually opposite polarities, a voltage signal having a smaller amplitude than said the same amplitude, and a voltage signal of 0, respectively with respect to the potential of a nonselected scanning electrode, in the writing period including said at least three phases, and said voltage signal of 0 is applied in the last phase among said at least three phases.

20   32.   A driving method according to Claim 31, wherein said smaller amplitude is one half of said the same   20
amplitude.

33.   A driving method according to Claim 27, wherein the duration of a continually applied voltage of the same polarity applied to a pixel on a scanning electrode among the scanning electrodes is two times the duration of the first phase in said writing period at the maximum.

25   34.   A driving method according to Claim 27, wherein said optical modulation material comprises a fer-   25
roelectric liquid crystal.

35.   A driving method according to Claim 34, wherein said ferroelectric liquid crystal comprises a chiral smectic liquid crystal.

36.   A driving method according to Claim 35, wherein said chiral smectic liquid crystal is disposed in a
30   layer thin enough to release the helical structure of the chiral smectic liquid crystal in the absence of an   30
electric field.

37.   An optical modulation apparatus comprising:

an optical modulation device comprising scanning electrodes and signal electrodes disposed opposite to and intersecting with the signal electrodes, and an optical modulation material disposed between the scan-
35   ning electrodes and the signal electrodes, a pixel being formed at each intersection of the scanning electro-   35
des and the signal electrodes and showing a contrast depending on the polarity of a voltage applied thereto; and

a driving unit for driving the optical modulation device according to a method which comprises, in a writing period for writing in all or prescribed pixels among the pixels on a selected scanning electrode
40   among said scanning electrodes, a first phase for applying a voltage of one polarity having an amplitude   40
exceeding a first threshold voltage of the optical modulation material to said all or prescribed pixels; and

a third phase for applying a voltage of the other polarity having an amplitude exceeding a second threshold voltage of the optical modulation material to a selected pixel and applying a voltage not exceeding the threshold voltages of the optical modulation material to the other pixels, respectively among said all or
45   prescribed pixels; a second phase not determining the contrast of said all or prescribed pixels being further   45
disposed between the first and third phases.

38.   An optical modulation apparatus according to Claim 37, wherein said optical modulation material comprises a ferroelectric liquid crystal.

39.   An optical modulation apparatus according to Claim 38, wherein said ferroelectric liquid crystal com-
50   prises a chiral smectic liquid crystal.   50

40.   An optical modulation apparatus according to Claim 39, wherein said chiral smectic liquid crystal is disposed in a layer thin enough to release the helical structure of the chiral smectic liquid crystal in the absence of an electric field.

41.   An optical modulation apparatus comprising:
55   an optical modulation device comprising scanning electrodes and signal electrodes disposed opposite to   55
and intersecting with the signal electrodes, and an optical modulation material disposed between the scan-
ning electrodes and the signal electrodes, a pixel being formed at each intersection of the scanning elec-
trodes and the signal electrodes and showing a contrast depending on the polarity of a voltage applied
thereto; and
60   a driving unit for driving the optical modulation device according to a method which comprises, in a   60
writing period for writing in all or prescribed pixels among the pixels on a selected scanning electrode
among said scanning electrodes, a first phase for applying a voltage of one polarity having an amplitude
exceeding a first threshold voltage of the optical modulation material to a nonselected pixel among said or
prescribed pixels; a second phase for applying a voltage of said one polarity having an amplitude exceeding
65   the first threshold voltage to a selected pixel among said all or prescribed pixels; and a third phase for   65

applying a voltage of the other polarity having an amplitude exceeding a second threshold voltage of the optical modulation material to the selected pixel.

42.   An optical modulation apparatus according to Claim 41, wherein said optical modulation material comprises a ferroelectric liquid crystal.

5   43.   An optical modulation apparatus according to Claim 42, wherein said ferroelectric liquid crystal comprises a chiral smectic liquid crystal.

44.   An optical modulation apparatus according to Claim 43, wherein said chiral smectic liquid crystal is disposed in a layer thin enough to release the helical structure of the chiral smectic liquid crystal in the absence of an electric field.

10   45.   An optical modulation apparatus comprising:

an optical modulation device comprising scanning electrodes and signal electrodes disposed opposite to and intersecting with the signal electrodes, and an optical modulation material disposed between the scanning electrodes and the signal electrodes, a pixel being formed at each intersection of the scanning electrodes and the signal electrodes and showing a contrast depending on the polarity of a voltag applied thereto; and

a driving unit for driving the optical modulation device according to a method which comprises: writing into all or prescribed pixels on a selected scanning electrode among the scanning electrodes in a writing period including at least three phases, and applying voltages of mutually opposite polarities at the first phase and the last phase among said at least three phases and each having an amplitude not exceeding the threshold voltages of said optical modulation material to the pixels on a nonselected scanning electrode.

49.   A driving method for an optical modulation device comprising scanning electrodes and signal electrodes disposed opposite to and intersecting with the signal electrodes, and an optical modulation material disposed between the scanning electrodes and the signal electrodes, a pixel being formed at each intersection of the scanning electrodes and the signal electrodes and showing a contrast depending on the polarity of a voltage applied thereto; said driving method comprising, in a writing period for writing in all or prescribed pixels among the pixels on a selected scanning electrode among said scanning electrodes:

a first phase for applying a voltage of one polarity having an amplitude exceeding a first threshold voltage of the optical modulation material to said all or prescribed pixels, and

a second phase for applying a voltage of the other polarity having an amplitude exceeding a second threshold voltage of the optical modulation material to a selected pixel and applying a voltage not exceeding the threshold voltages of the optical modulation material to the other pixels, respectively among said all or prescribed pixels,

the duration of a continually applied voltage of the same polarity applied to a pixel on a scanning electrode among the scanning electrodes being 2.5 times the duration of the first phase in said writing period at the maximum.

50.   A driving method according to Claim 49, wherein said optical modulation material comprises a ferroelectric liquid crystal.

51.   A driving method according to Claim 50, wherein said ferroelectric liquid crystal comprises a chiral smectic liquid crystal.

52.   A driving method according to Claim 51, wherein said chiral smectic liquid crystal is disposed in a layer thin enough to release the helical structure of the chiral smectic liquid crystal in the absence of an electric field.

53.   A driving method for an optical modulation device comprising scanning electrodes, signal electrodes disposed opposite to and intersecting with the signal electrodes, and an optical modulation material disposed between the scanning electrodes and the signal electrodes, each intersection of the scanning electrodes and the signal electrodes constituting a pixel in combination with the optical modulation material so as to provide pixels arranged in a matrix, the contrast of each pixel being discriminated depending on the direction of an electric field applied thereto; said driving method comprising:

a first step of applying a voltage of one polarity exceeding a first threshold voltage of the optical modulation material to all or a prescribed number of the pixels arranged in a matrix, and

a second step of applying a scanning selection signal including a first phase and a second phase having voltage signals of mutually opposite polarities with respect to a reference potential (the potential of a nonselected scanning electrode) to a selected scanning electrode among the scanning electrodes, thereby to apply a voltage of the other polarity exceeding a second threshold voltage of the optical modulation material to a selected pixel on the selected scanning electrode at the second phase and apply a voltage not exceeding the threshold voltages of the optical modulation material to the nonselected pixels on the selected scanning electrode at the first and second phases.

54.   A driving method according to Claim 53, wherein in a writing period for effecting said second step, and the first and second phases are disposed in a former half and a second half, respectively, of the writing period.

55.   A driving method according to Claim 53, wherein a signal electrode electrically connected to said selected pixel on the selected scanning electrode is supplied with an information signal comprising voltage signals of polarities opposite to those of the scanning selection signal at the first and second phases, respectively, with respect to a reference potential (the potential of a nonselected scanning electrode).

56.   A driving method according to Claim 53, wherein a signal electrode electrically connected to said

selected pixel on the selected scanning electrode is supplied with voltage signals of polarities opposite to those of voltage signals applied to a signal electrode electrically connected to a nonselected pixel on the selected scanning electrode at the first and second phases, respectively, with respect to a reference potential (the potential of a nonselected scanning electrode).

5   57.   A driving method according to Claim 53, wherein said scanning selection signal comprises voltage signals of the same amplitude at the first and second phases.

58.   A driving method according to Claim 53, wherein the duration of a continually applied voltage of the same polarity applied to a pixel on a scanning electrode among the scanning electrodes is two times the duration of the first phase at the maximum.

10   59.   A driving method according to Claim 53, wherein in said first step, voltage signals for providing said voltage of one polarity exceeding a first threshold voltage of the optical modulation material are applied to all the scanning electrodes and signal electrodes, respectively, electrically connected to said all or a prescribed number of the pixels.

60.   A driving method according to Claim 59, wherein the voltage signals applied to the scanning electro-
15   des and the signal electrodes have mutually opposite polarities with respect to a reference potential (the potential of a nonselected scanning electrode).

61.   A driving method according to Claim 53, wherein in said first step, alternating voltage signals for providing voltages of one and the other polarities exceeding the first and second threshold voltages of the optical modulation material are applied at one time to all the scanning electrodes and signal electrodes,
20   respectively, electrically connected to said all or a prescribed number of the pixels.

62.   A driving method according to Claim 61, wherein the alternating voltage signals applied to the scanning electrodes and the signal electrodes are of mutually reverse phases.

63.   A driving method according to Claim 53, wherein said optical modulation material comprises a ferroelectric liquid crystal.

25   64.   A driving method according to Claim 63, wherein said ferroelectric liquid crystal comprises a chiral smectic liquid crystal.

65.   A driving method according to Claim 64, wherein said chiral smectic liquid crystal is disposed in a layer thin enough to release the helical structure of the chiral smectic liquid crystal in the absence of an electric field.

30   66.   An optical modulation apparatus comprising:

an optical modulation device comprising scanning electrodes, signal electrodes disposed opposite to and intersecting with the signal electrodes, and an optical modulation material disposed between the scanning electrodes and the signal electrodes, each intersection of the scanning electrodes and the signal electrodes constituting a pixel in combination with the optical modulation material so as to provide pixels arranged in a
35   matrix, the contrast of each pixel being discriminated depending on the direction of an electric field applied thereto; and

a driving unit for driving the optical modulation device according to a method comprising: a first step of applying a voltage of one polarity exceeding a first threshold voltage of the optical modulation material to all or a prescribed number of the pixels arranged in a matrix, and a second step of applying a scanning selection
40   signal including a first phase and a second phase having voltage signals of mutually opposite polarities with respect to a reference potential (the potential of a nonselected scanning electrode) to a selected scanning electrode among the scanning electrodes, thereby to apply a voltage of the other polarity exceeding a second threshold voltage of the optical modulation material to a selected pixel on the selected scanning electrode at the first phase and apply a voltage not exceeding the second threshold voltage of the optical modulation
45   material to the pixels on the selected scanning electrode at the second phase.

67.   An optical modulation apparatus according to Claim 66, wherein said optical modulation material comprises a ferroelectric liquid crystal.

68.   An optical modulation apparatus according to Claim 67, wherein said ferroelectric liquid crystal comprises a chiral smectic liquid crystal.

50   69.   An optical modulation apparatus according to Claim 68, wherein said chiral smectic liquid crystal is disposed in a layer thin enough to release the helical structure of the chiral smectic liquid crystal in the absence of an electric field.

70.   A dirving method for an optical modulation device comprising scanning electrodes, signal electrodes disposed opposite to and intersecting with the signal electrodes, and an optical modulation material dis-
55   posed between the scanning electrodes and the signal electrodes, each intersection of the scanning electrodes and the signal electrodes constituting a pixel in combination with the optical modulation material so as to provide pixels arranged in a matrix, the contrast of each pixel being discriminated depending on the direction of an electric field applied thereto; said driving method comprising:

a first step of applying a voltage of one polarity exceeding a first threshold voltage of the optical modula-
60   tion material to all or a prescribed number of the pixels arranged in a matrix, and

a second step including a second phase for applying a voltage of the other polarity exceeding a second threshold voltage of the optical modulation material to a selected pixel on a selected scanning electrode among the scanning electrodes so as to determine the contrast of the selected pixel, and a first phase for not determining the contrast of the selected pixel disposed prior to the second phase.

65   71.   A driving method according to Claim 70, wherein a voltage not exceeding the threshold voltages of

the optical modulation material is applied to a nonselected pixel on the selected scanning electrode at the first and second phases.

72.   A driving method according to Claim 70, wherein the duration of a continually applied voltage of the same polarity applied to a pixel on a scanning electrode among the scanning electrodes is two times the
5 duration of the first phase at the maximum.

73.   A driving method according to Claim 70, wherein in said first phase, said selected pixel on the selected scanning electrode is supplied with a voltage exceeding the first threshold voltage of the optical modulation material.

74.   A driving method according to Claim 70, wherein said optical modulation material comprises a fer-
10 roelectric liquid crystal.

75.   A driving method according to Claim 74, wherein said ferroelectric liquid crystal comprises a chiral smectic liquid crystal.

76.   A driving method according to Claim 75, wherein said chiral smectic liquid crystal is disposed in a layer thin enough to release the helical structure of the chiral smectic liquid crystal in the absence of an
15 electric field.

77.   An optical modulation apparatus comprising:
an optical modulation device comprising scanning electrodes, signal electrodes disposed opposite to and intersecting with the signal electrodes, and an optical modulation material disposed between the scanning electrodes and the signal electrodes, each intersection of the scanning electrodes and the signal electrodes
20 constituting a pixel in combination with the optical modulation material so as to provide pixels arranged in a matrix, the contrast of each pixel being discriminated depending on the direction of an electric field applied thereto; and
a driving unit for driving the optical modulation device according to a method comprising: a first step of applying a voltage of one polarity exceeding a first threshold voltage of the optical modulation material to all
25 or a prescribed number of the pixels arranged in a matrix, and a second step of applying a scanning selection signal including a first phase and a second phase having voltage signals of mutually opposite polarities with respect to a reference potential (the potential of a nonselected scanning electrode) to a selected scanning electrode among the scanning electrodes, thereby to apply a voltage of the other polarity exceeding a second threshold voltage of the optical modulation material to a selected pixel on the selected scanning electrode at
30 the first phase and apply a voltage not exceeding the second threshold voltage of the optical modulation material to the pixels on the selected scanning electrode at the second phase.

78.   An optical modulation apparatus according to Claim 77, wherein said optical modulation material comprises a ferroelectric liquid crystal.

79.   An optical modulation apparatus according to Claim 78, wherein said ferroelectric liquid crystal com-
35 prises a chiral smectic liquid crystal.

80.   An optical modulation apparatus according to Claim 79, wherein said chiral smectic liquid crystal is disposed in a layer thin enough to release the helical structure of the chiral smectic liquid crystal in the absence of an electric field.

81.   A method of driving an optical modulation device comprising matrixed scanning and signal elec-
40 trodes with electro-optical material at the intersections forming pixels, wherein during the time one scanning electrode is addressed, the integral of the {modules of voltage} over time applied to each pixel along each non-addressed scanning electrode is more than 2.5 times the {modules of the integral} of voltage over time applied to such pixels.

82.   A method as claimed in claim 81, wherein the time during which each scanning electrode is addressed
45 is divided into at least three phases.

83.   A method or apparatus for driving an optical modulation device substantially as described in the description with reference to the drawings.

Amendments to the claims have been filed, and have the following effect:-
50 (b) New or textually amended claims have been filed as follows:-

46.   An optical modulation apparatus according to claim 45, wherein said optical modulation material comprises a ferroelectric liquid crystal.

47.   An optical modulation apparatus according to claim 46, wherein said ferroelectric liquid crystal com-
55 prises a chiral smectic liquid crystal.

48.   An optical modulation apparatus according to claim 47, wherein said chiral smectic liquid crystal is disposed in a layer thin enough to release the helical structure of the chiral smectic liquid in the absence of an electric field.