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Optical modulation device and driving method therefor

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GB 2117157 A
GB 2075738 A
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WO 81/00026 A1

(58) Field of search

As for published application
2156131 A *viz:*
UK CL G5C
updated as appropriate

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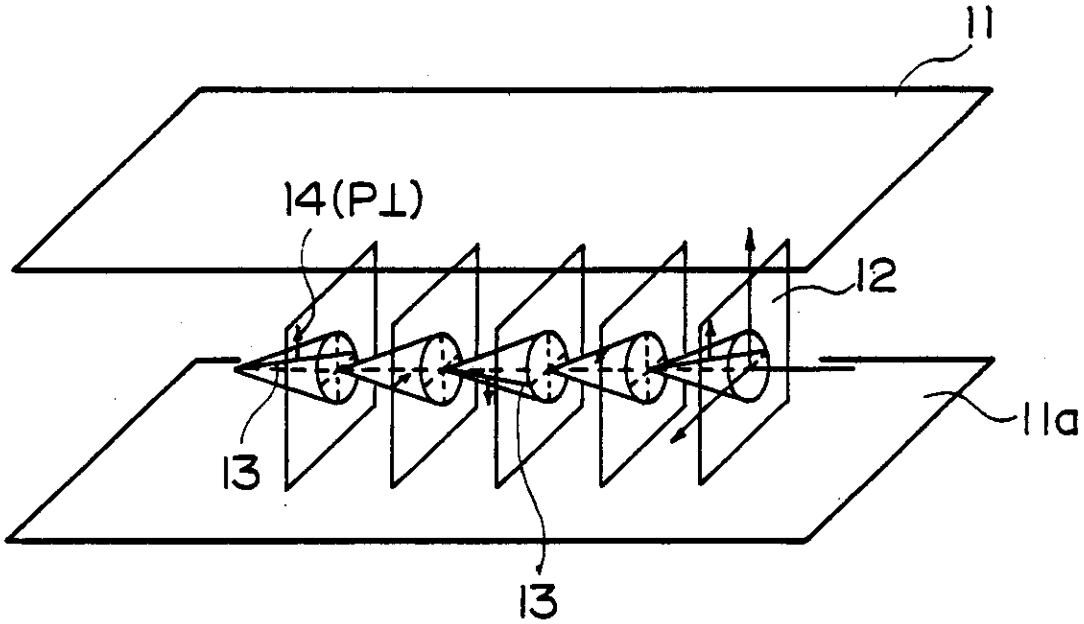
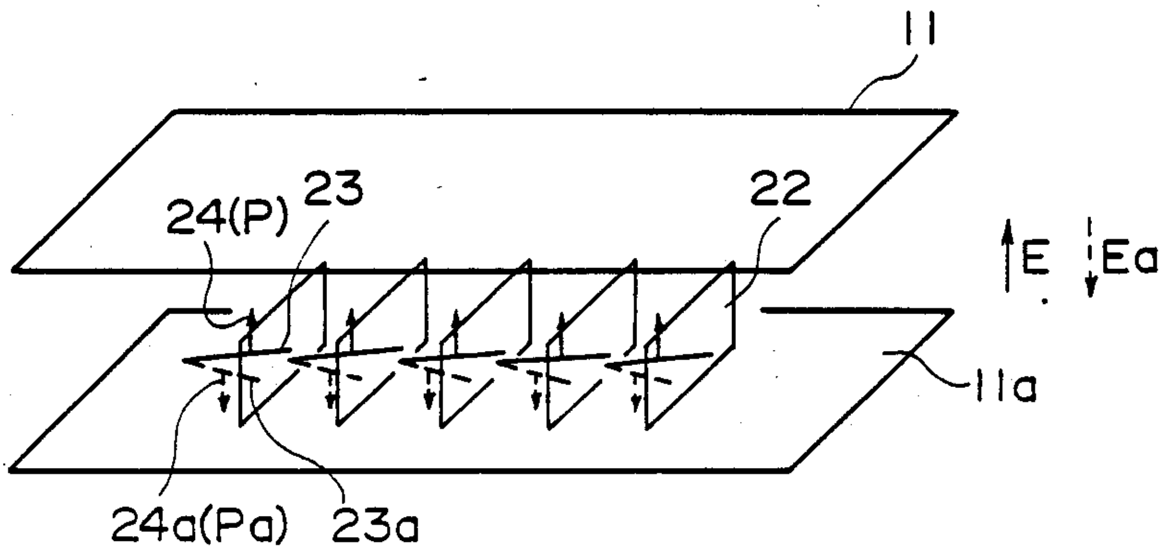


F I G. 1



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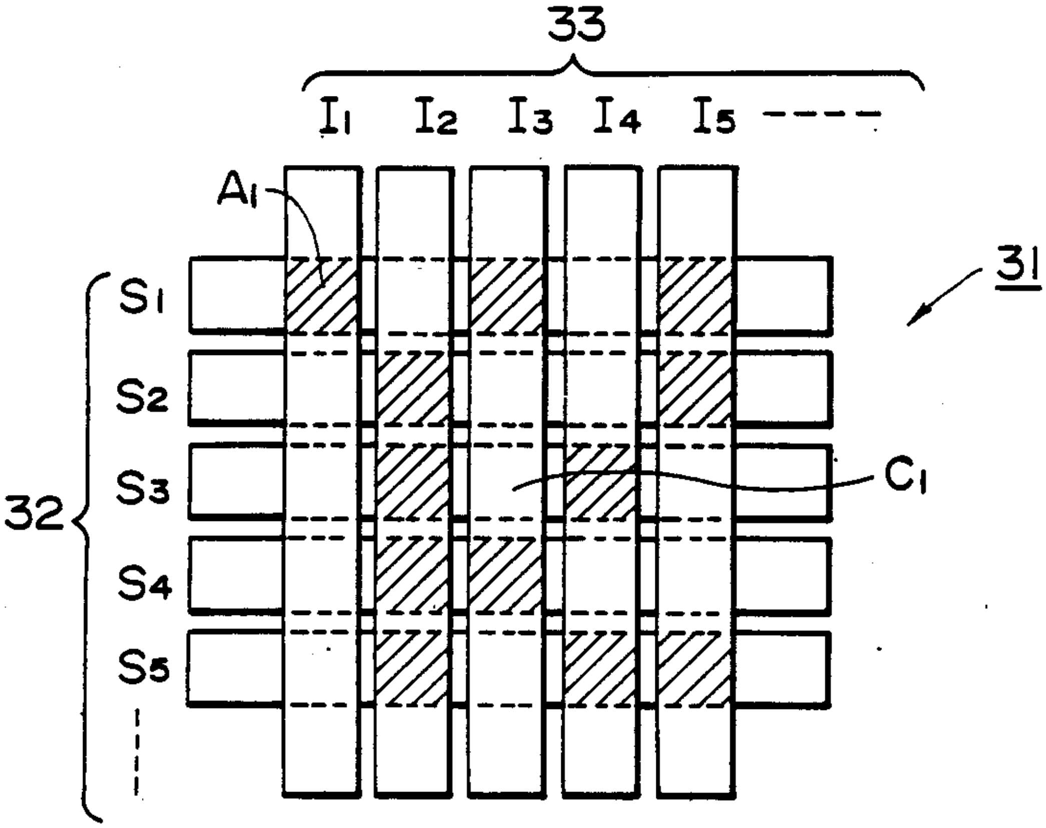

F I G. 3A

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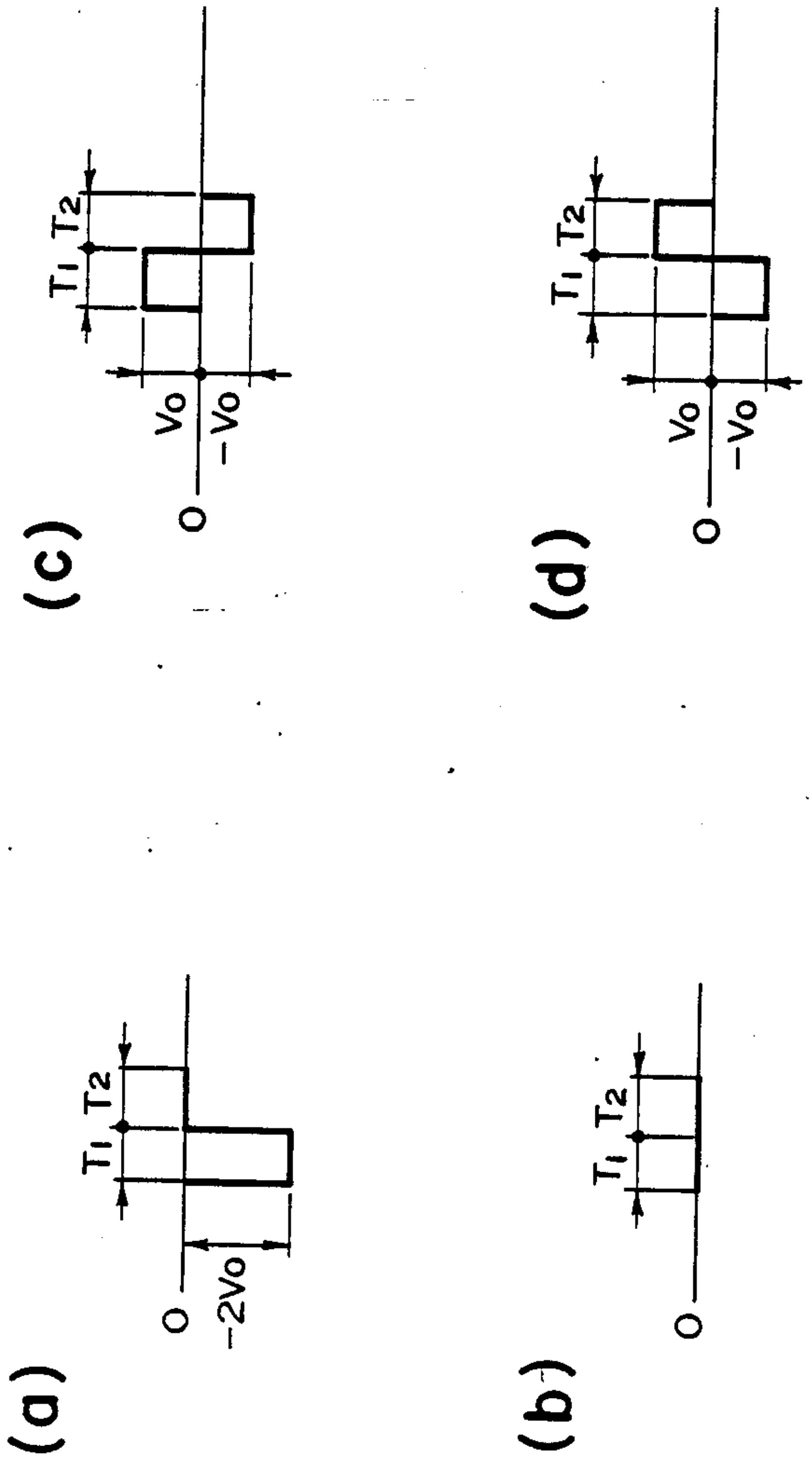
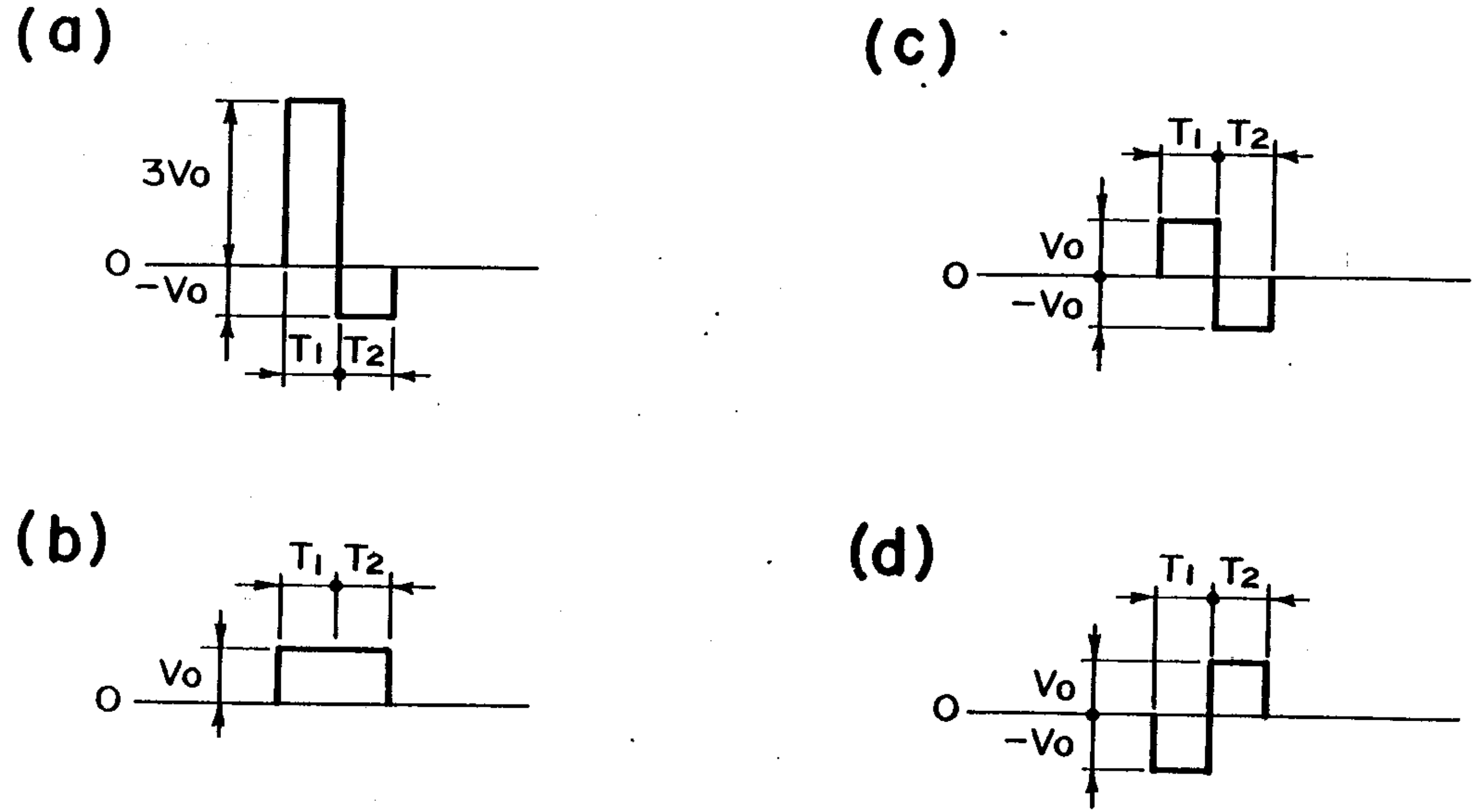


FIG. 3B



F I G. 3C

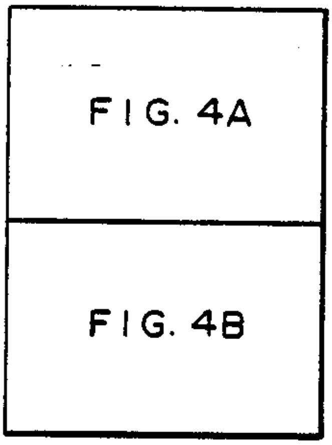


FIG. 4

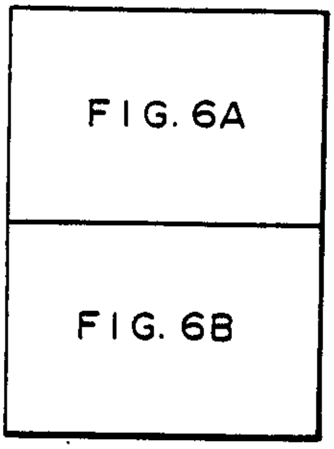


FIG. 6

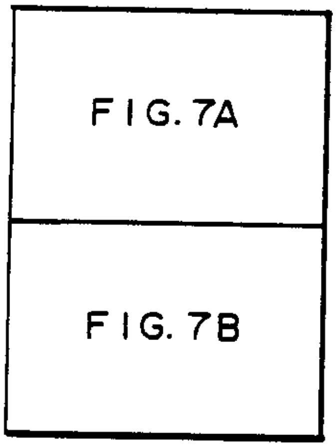


FIG. 7

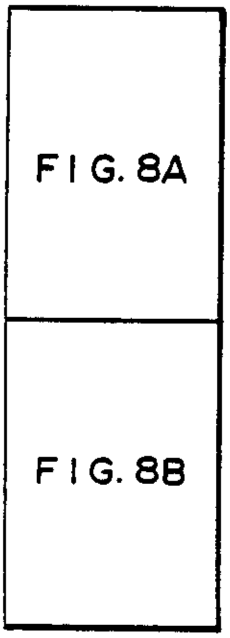


FIG. 8

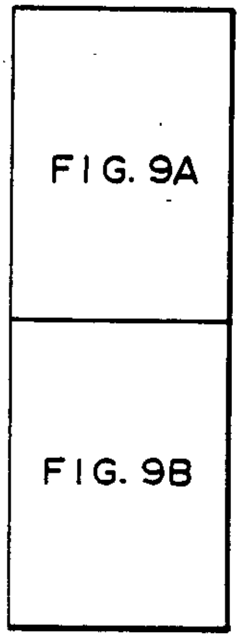


FIG. 9

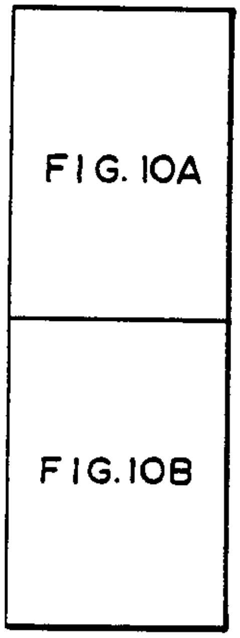


FIG. 10

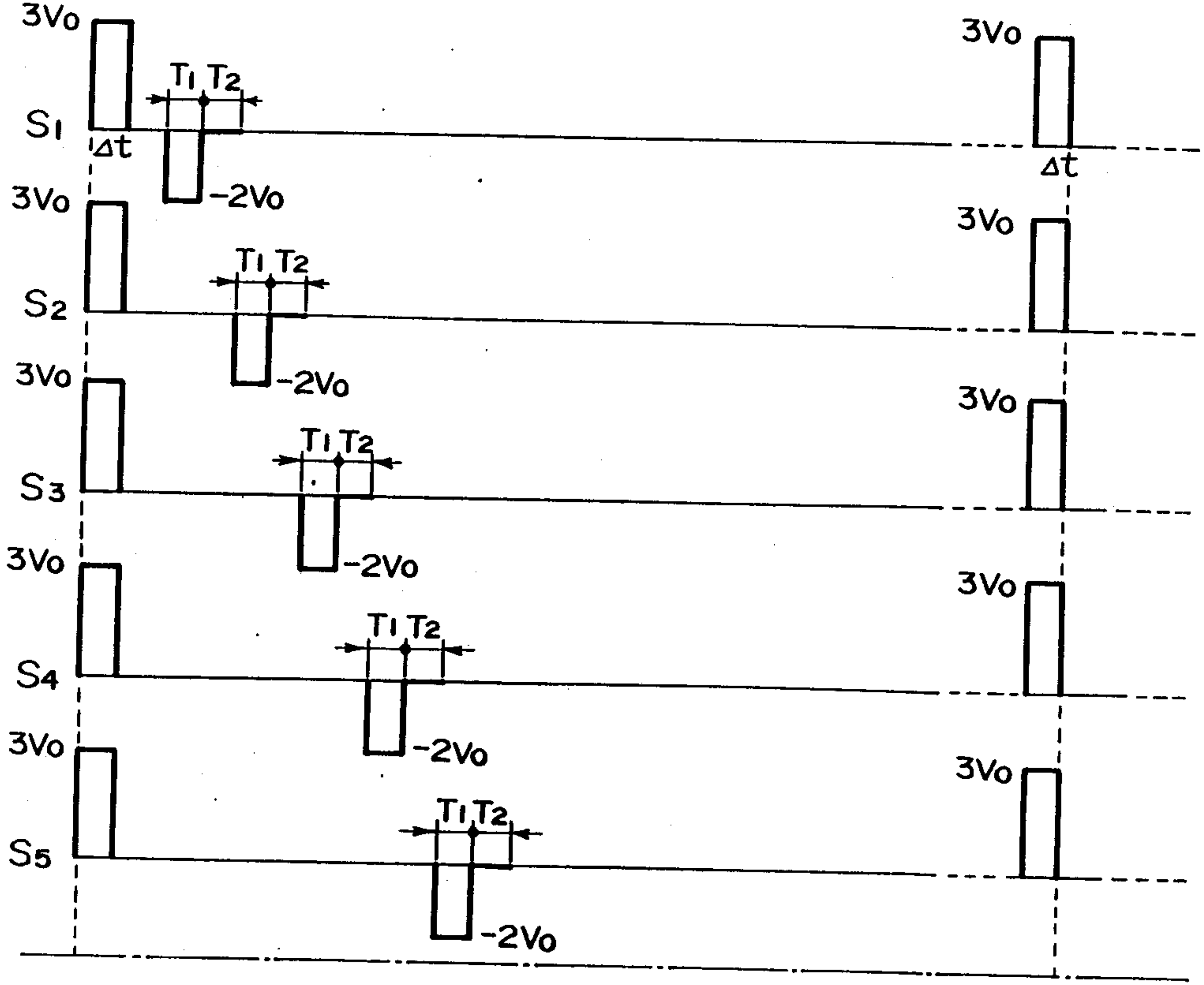


FIG. 4A

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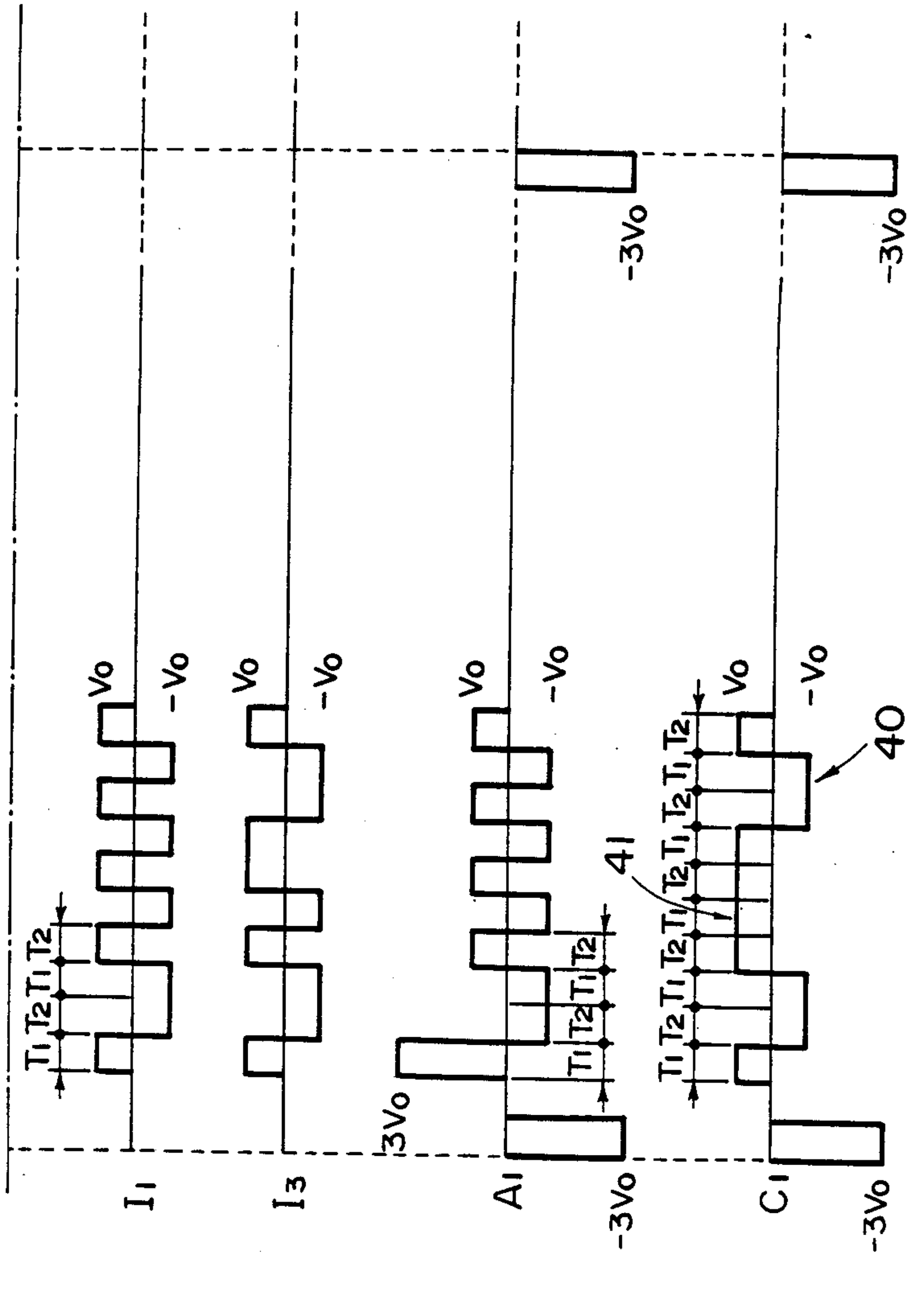

FIG. 4B

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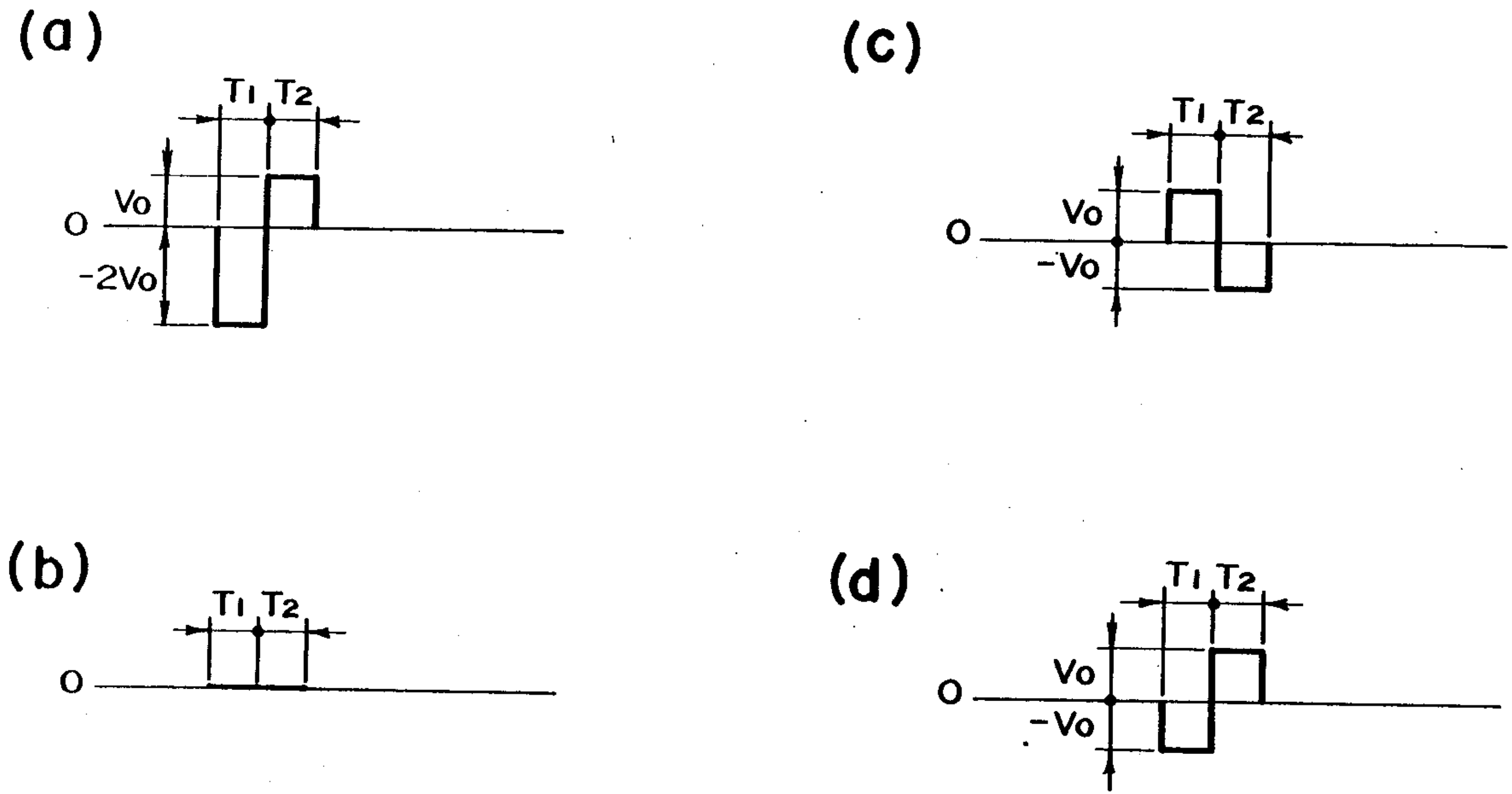
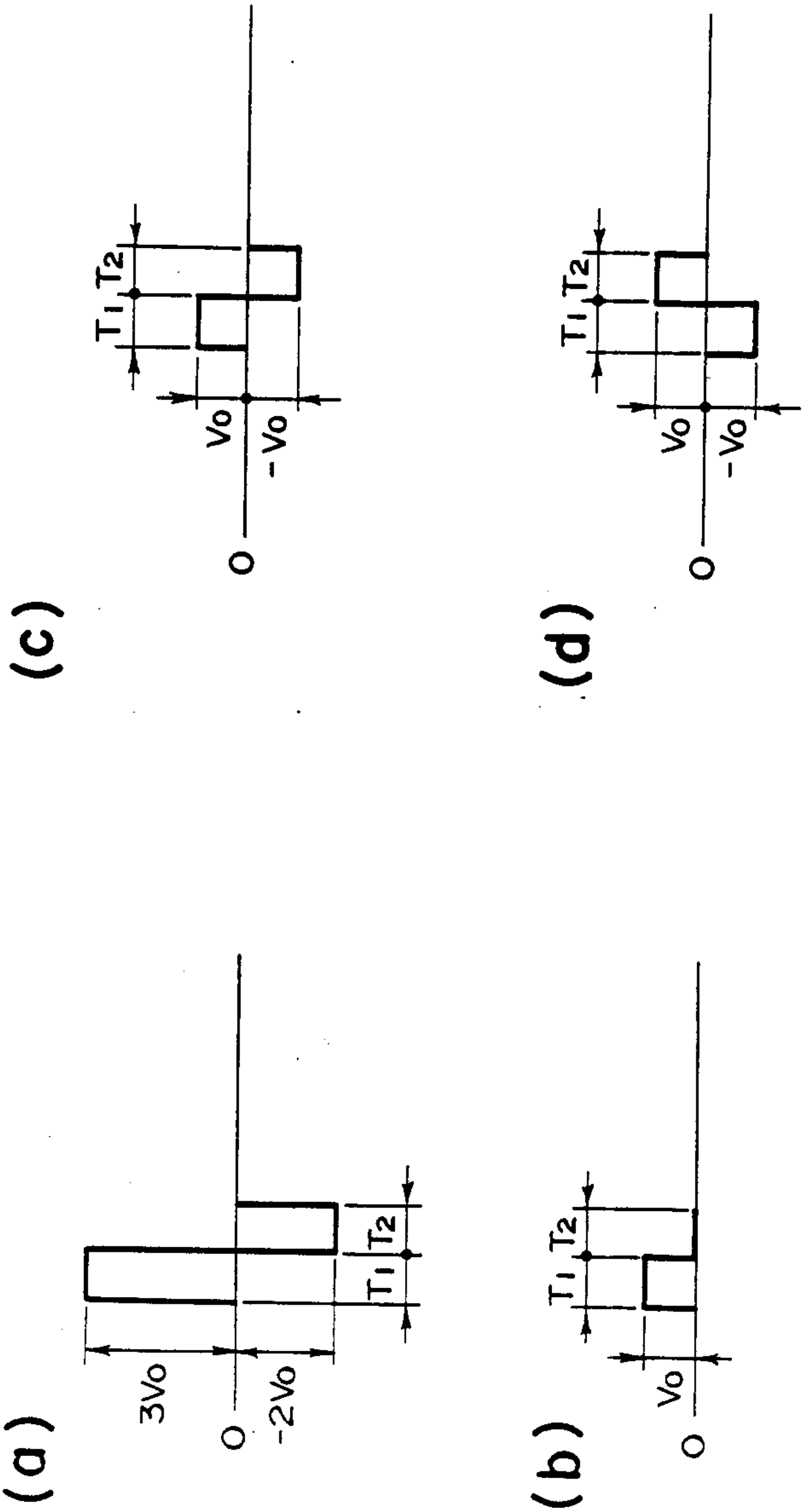


FIG. 5A



F I G. 5B

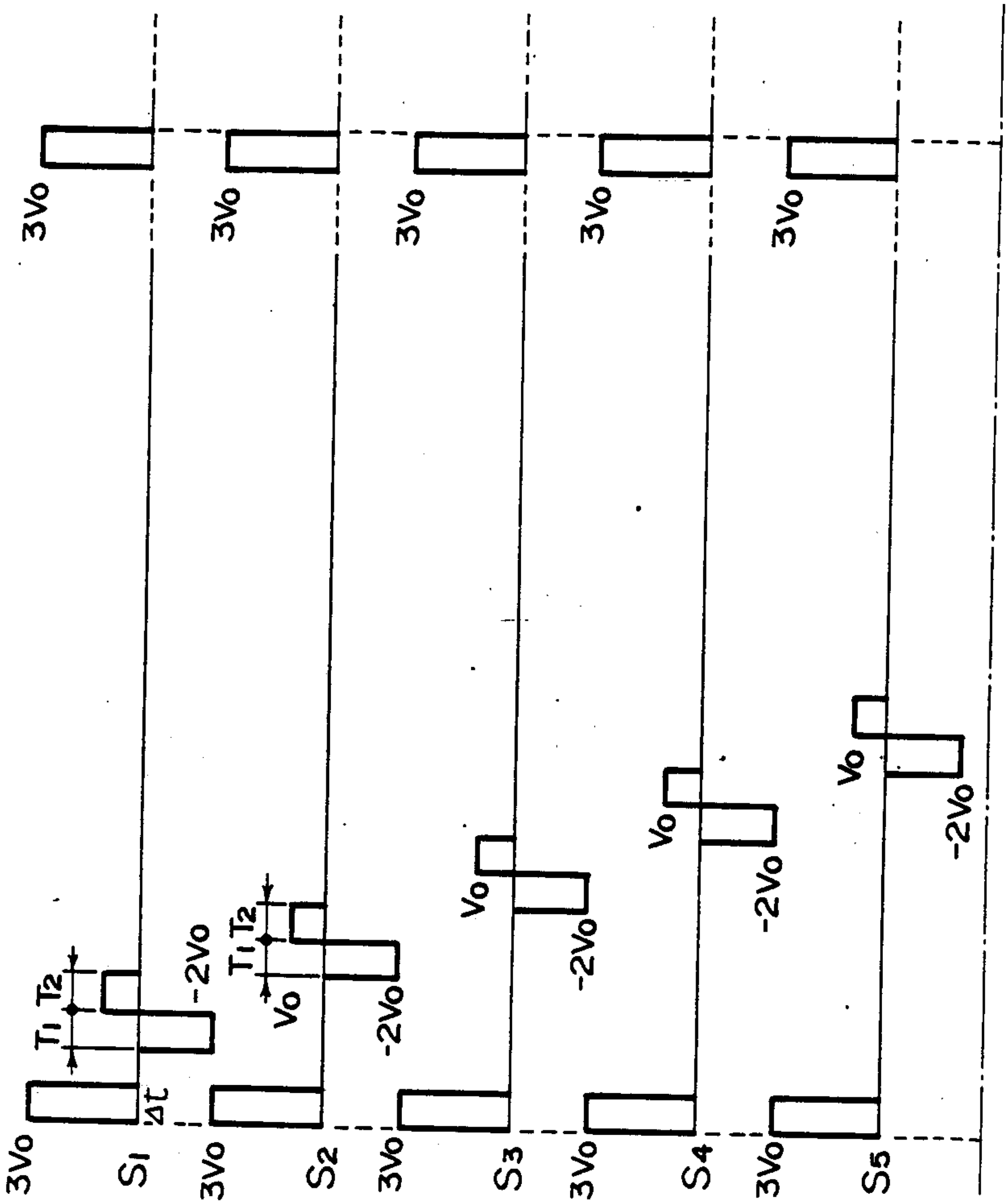
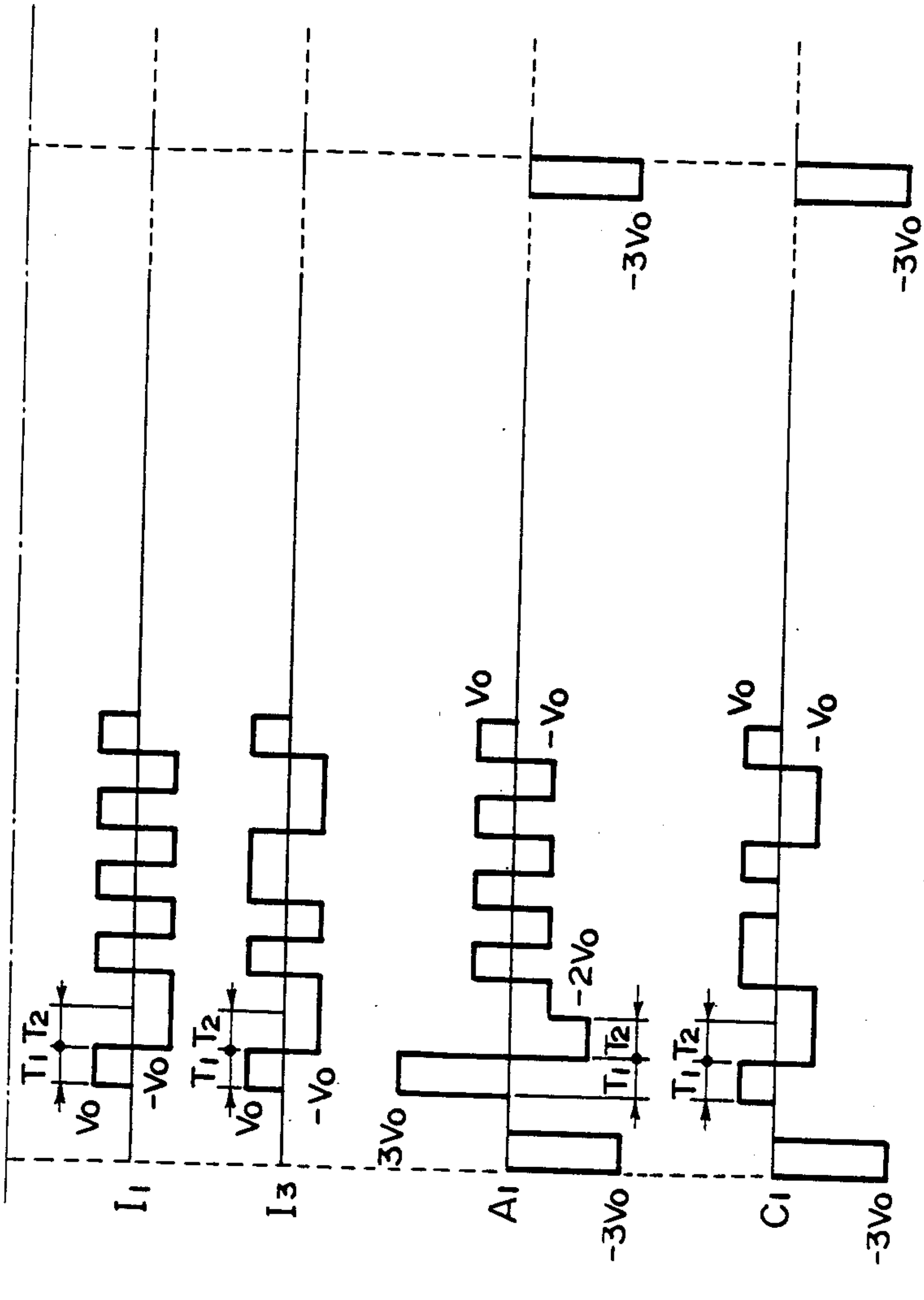

3Vo
S1
Δt
T1 T2
-2Vo
3Vo
S2
Vo
-2Vo
3Vo
S3
Vo
-2Vo
3Vo
S4
Vo
-2Vo
3Vo
S5
Vo
-2Vo

FIG. 6A



F I G. 6B

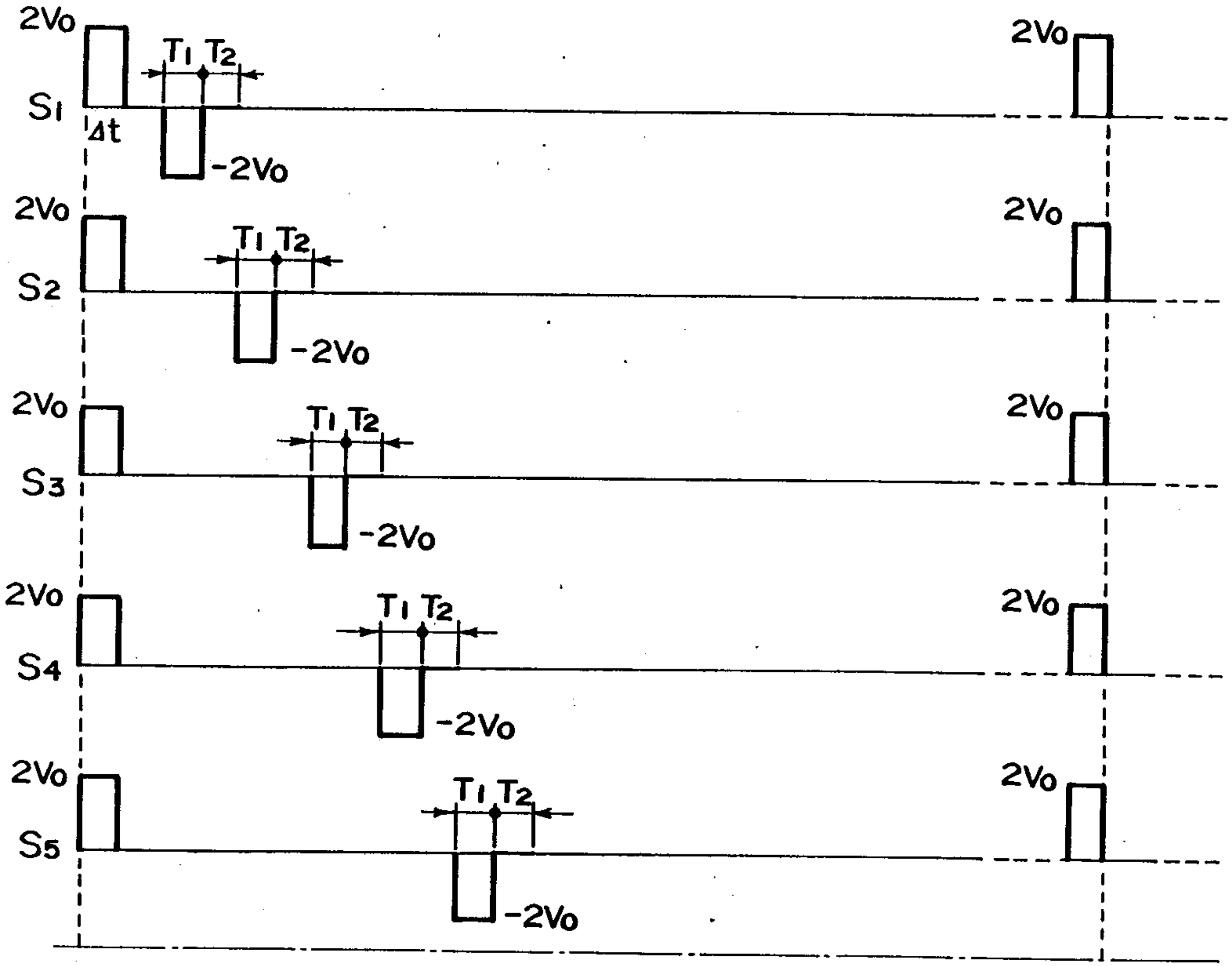

2Vo
S1
Δt
T1 T2
-2Vo
2Vo
S2
T1 T2
-2Vo
2Vo
S3
T1 T2
-2Vo
2Vo
S4
T1 T2
-2Vo
2Vo
S5
T1 T2
-2Vo
2Vo
2Vo
2Vo
2Vo
2Vo

FIG. 7A

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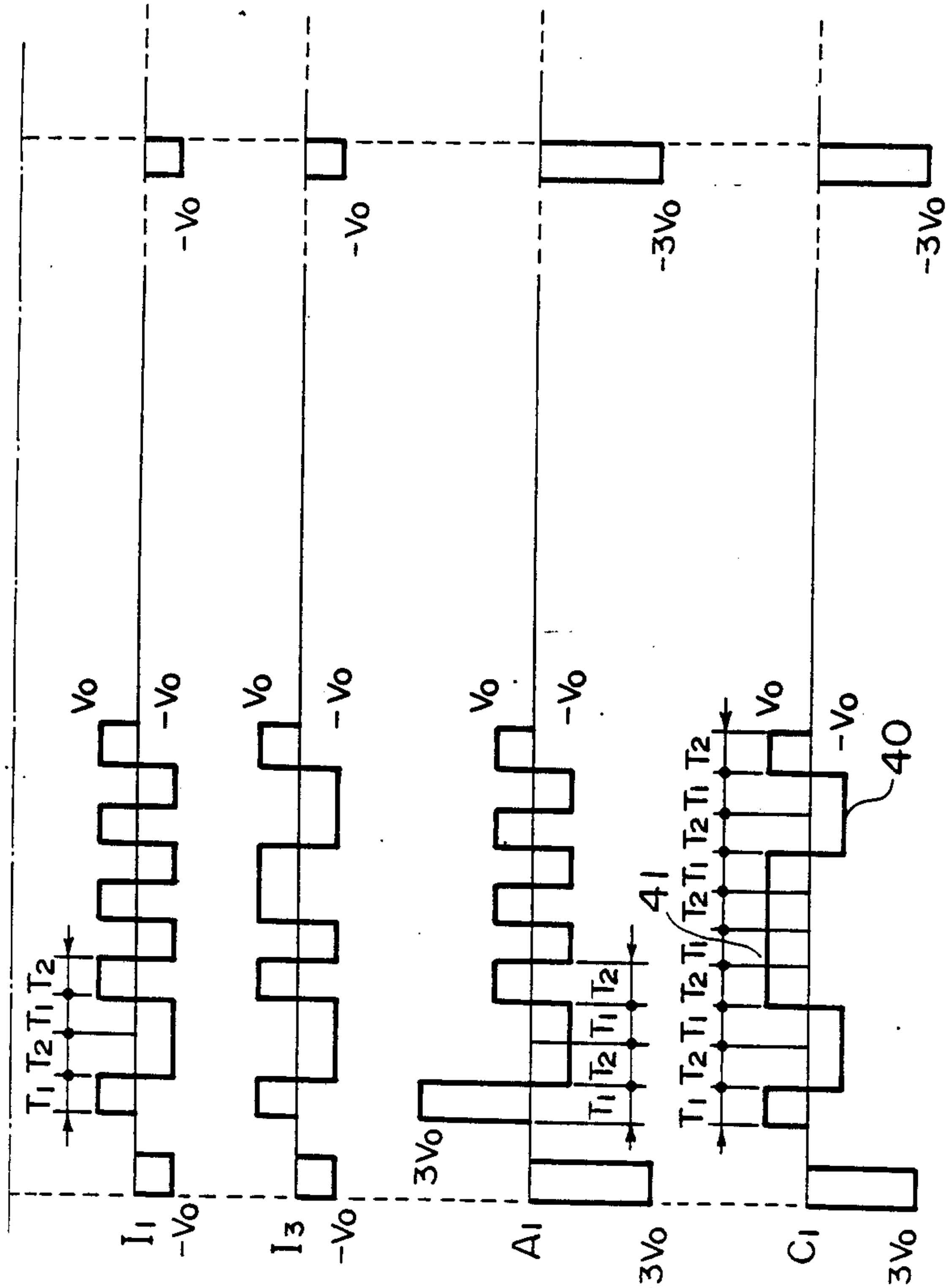


FIG. 7B

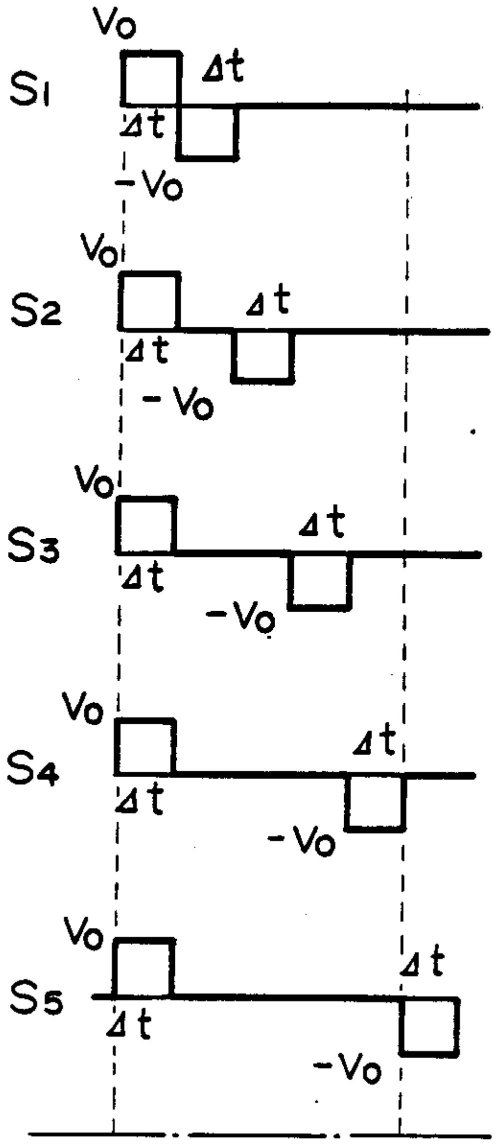


FIG. 8A

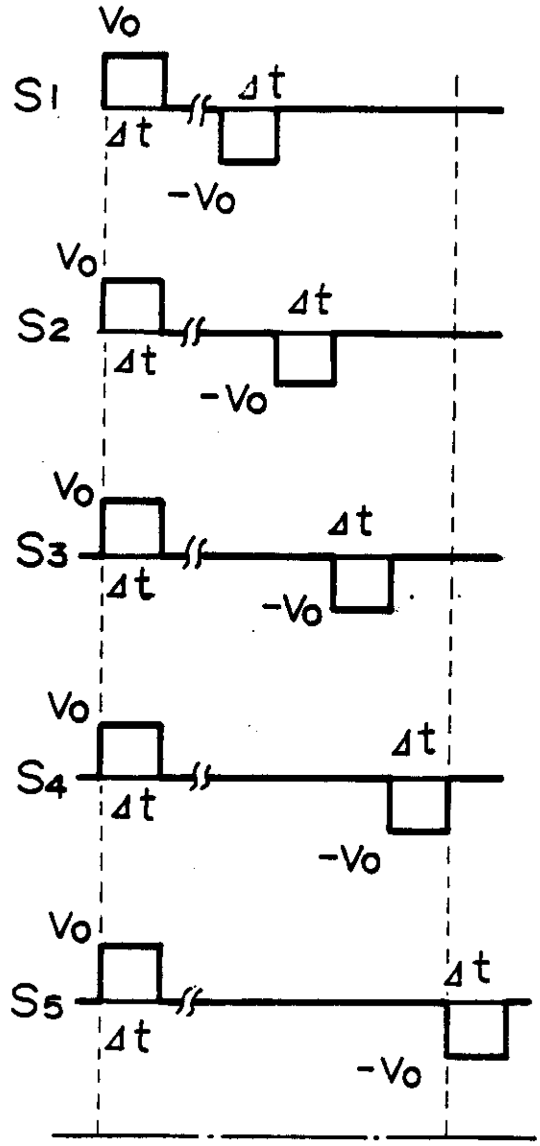
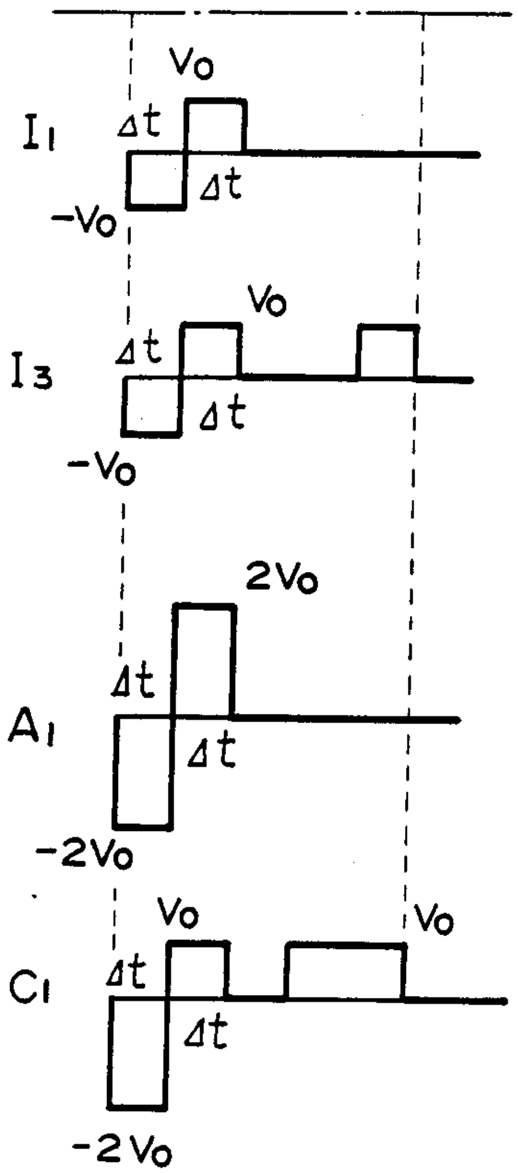
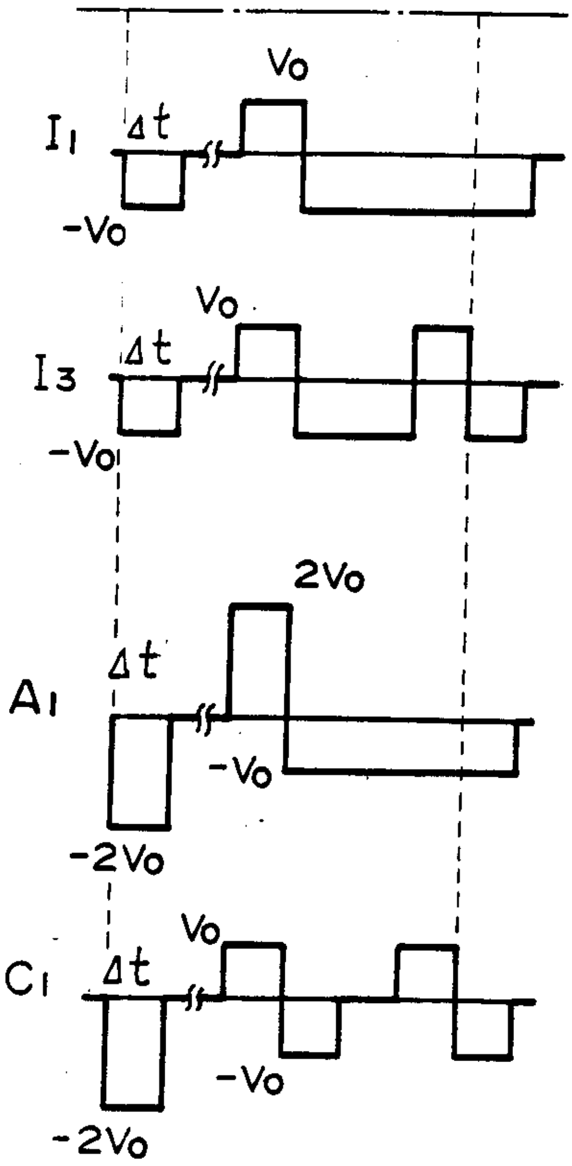


FIG. 9A



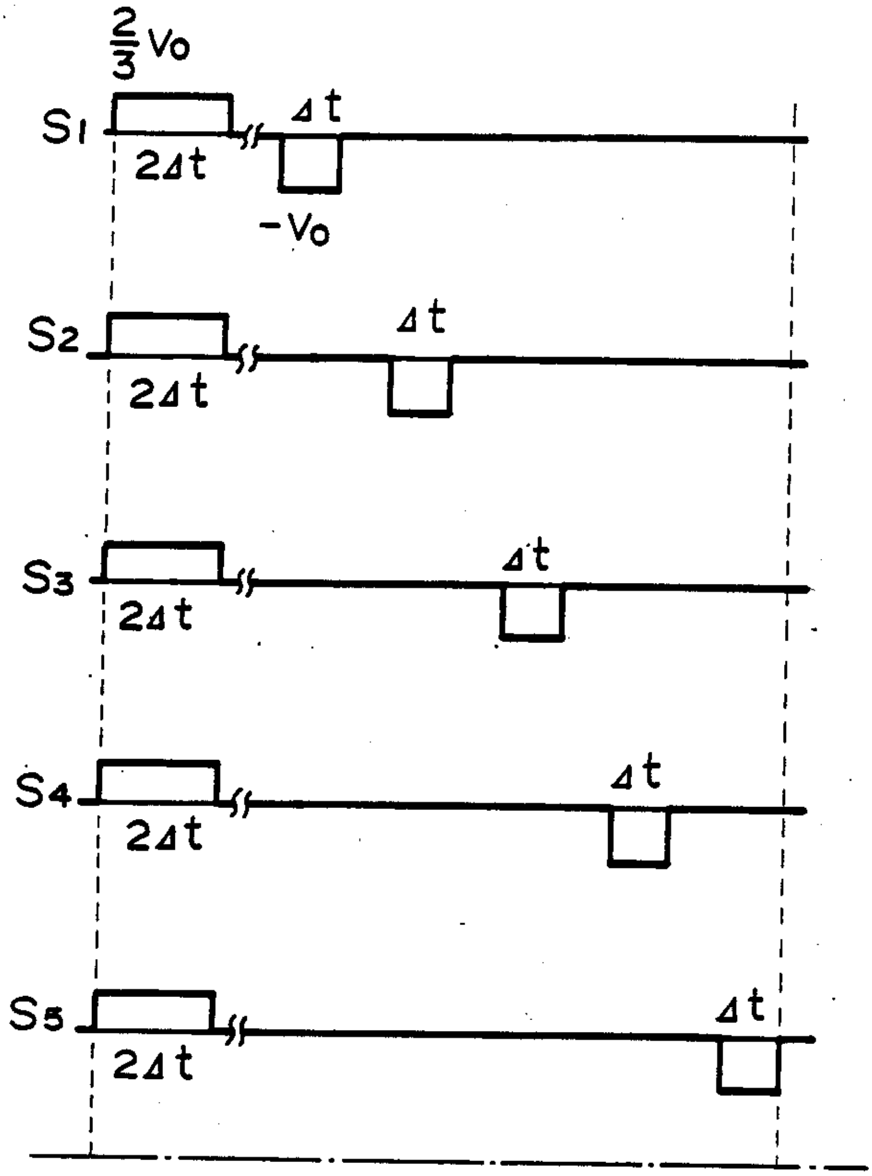
I1
Vo
Δt
Δt
-Vo
I3
Vo
Δt
Δt
-Vo
A1
2Vo
Δt
Δt
-2Vo
C1
Vo
Vo
Δt
Δt
-2Vo

FIG. 8B

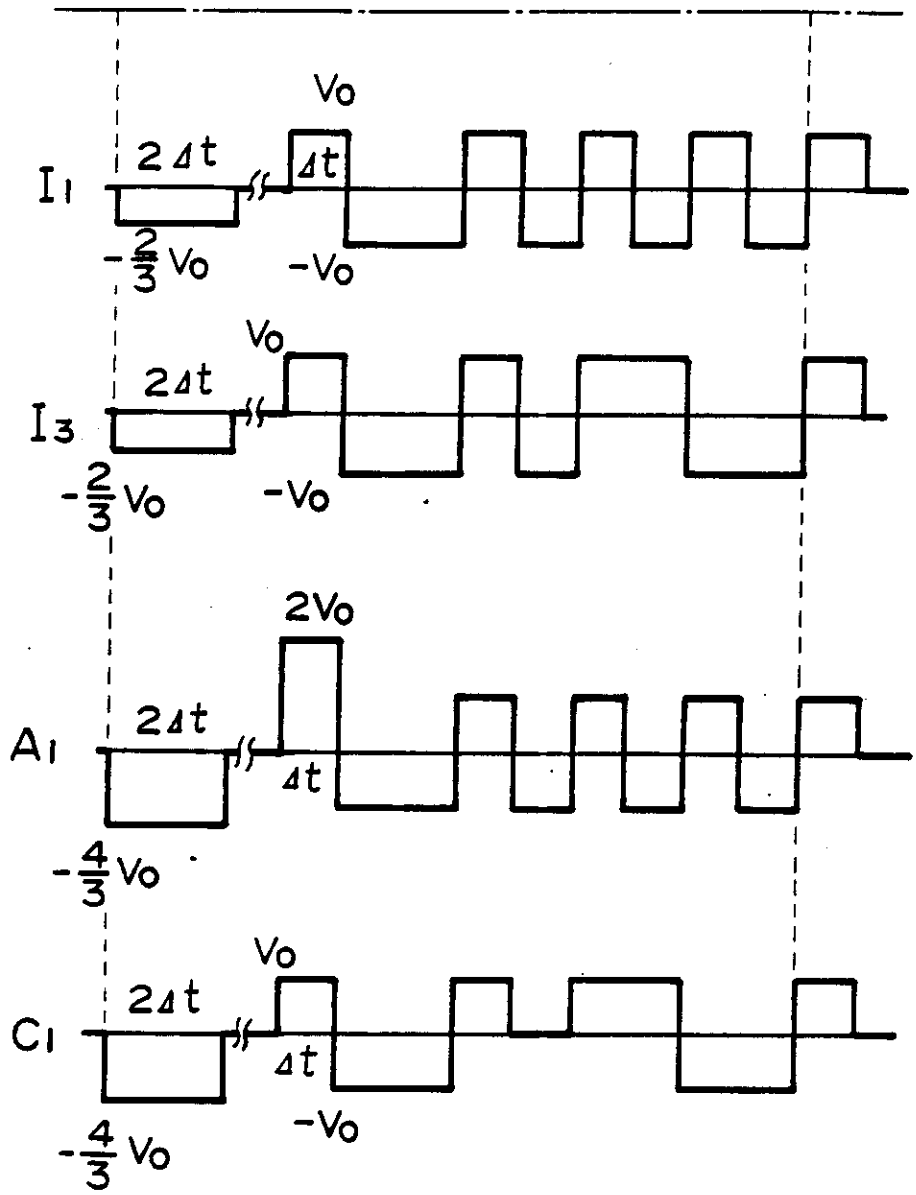


I1
Vo
Δt
-Vo
I3
Vo
Δt
-Vo
A1
2Vo
Δt
-Vo
-2Vo
C1
Vo
Δt
-Vo
-2Vo

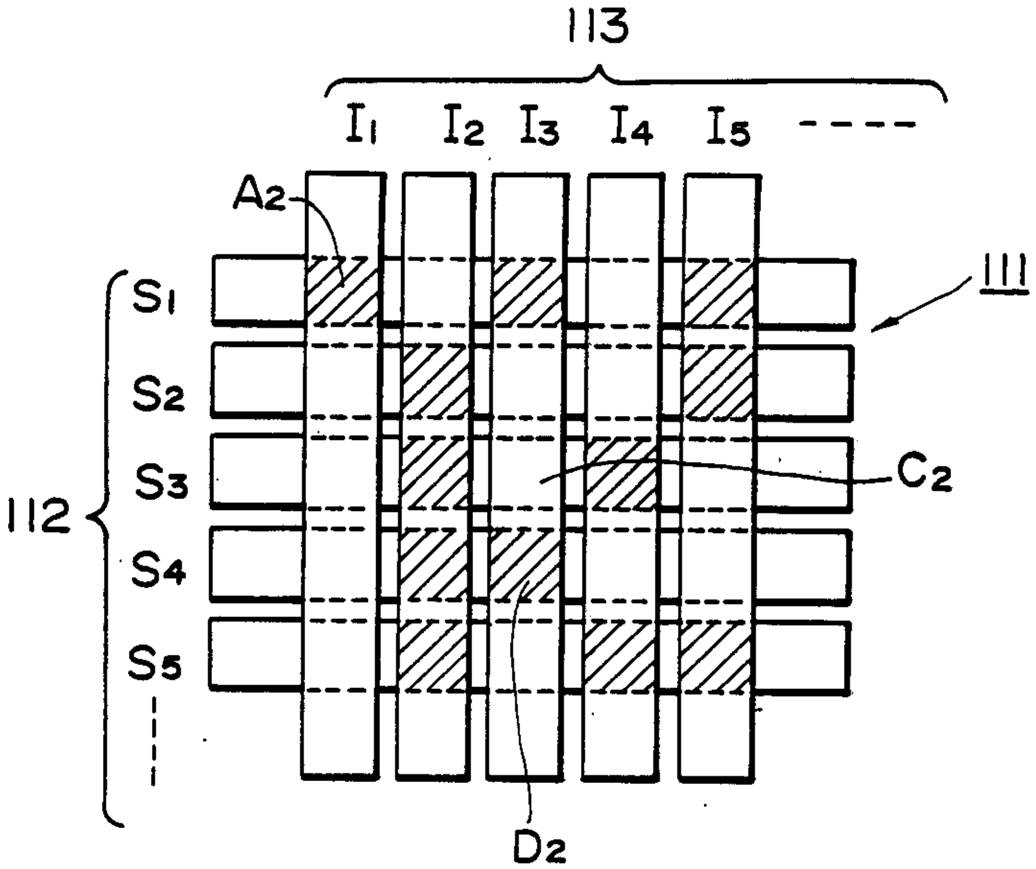
FIG. 9B



F I G. 10A


I1
2Δt
Vo
Δt
$-\frac{2}{3}$ Vo
-Vo
I3
2Δt
Vo
$-\frac{2}{3}$ Vo
-Vo
A1
2Δt
2Vo
Δt
$-\frac{4}{3}$ Vo
C1
2Δt
Vo
Δt
-Vo
$-\frac{4}{3}$ Vo

F I G. 10B



F I G. 11A

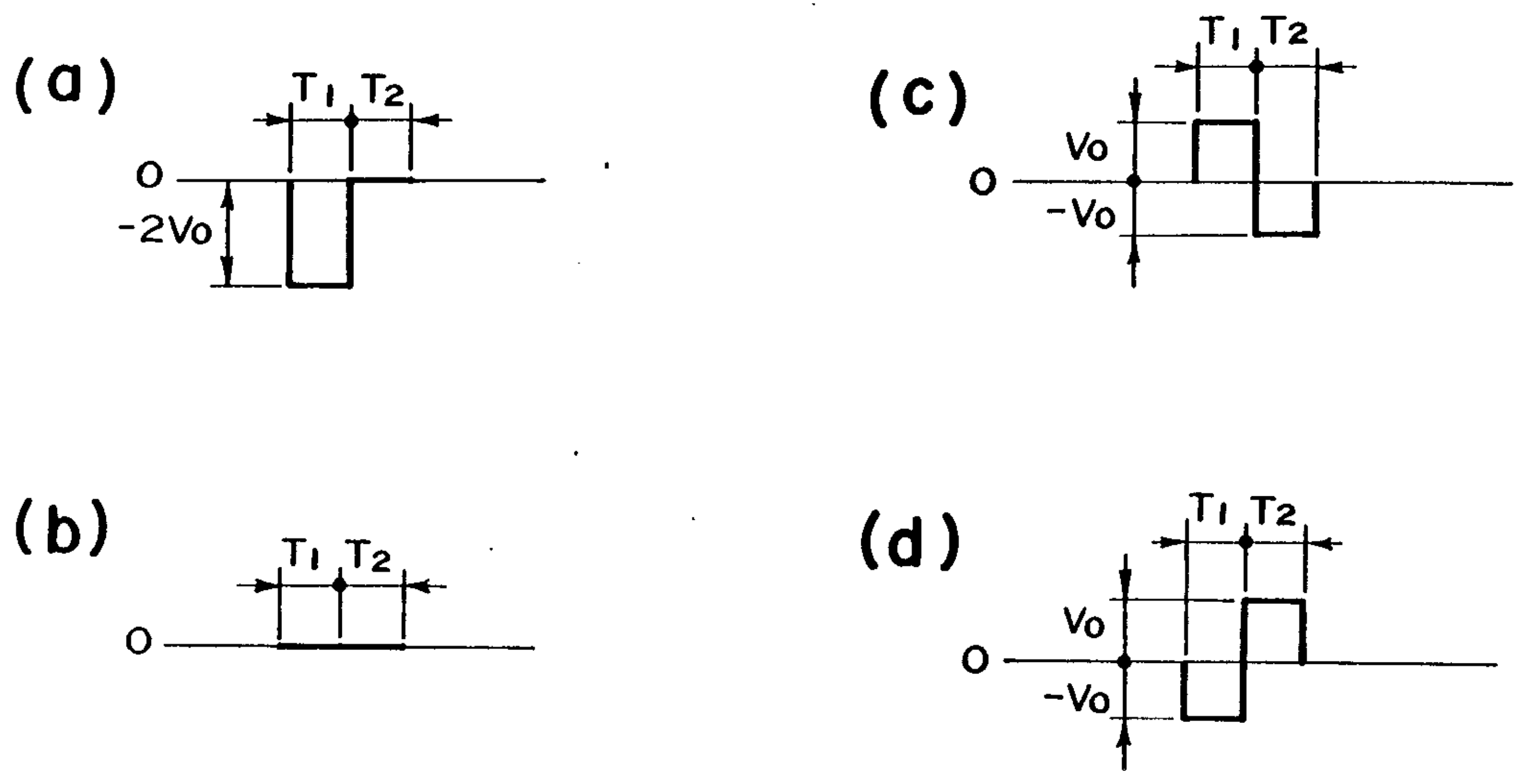


FIG. 11B

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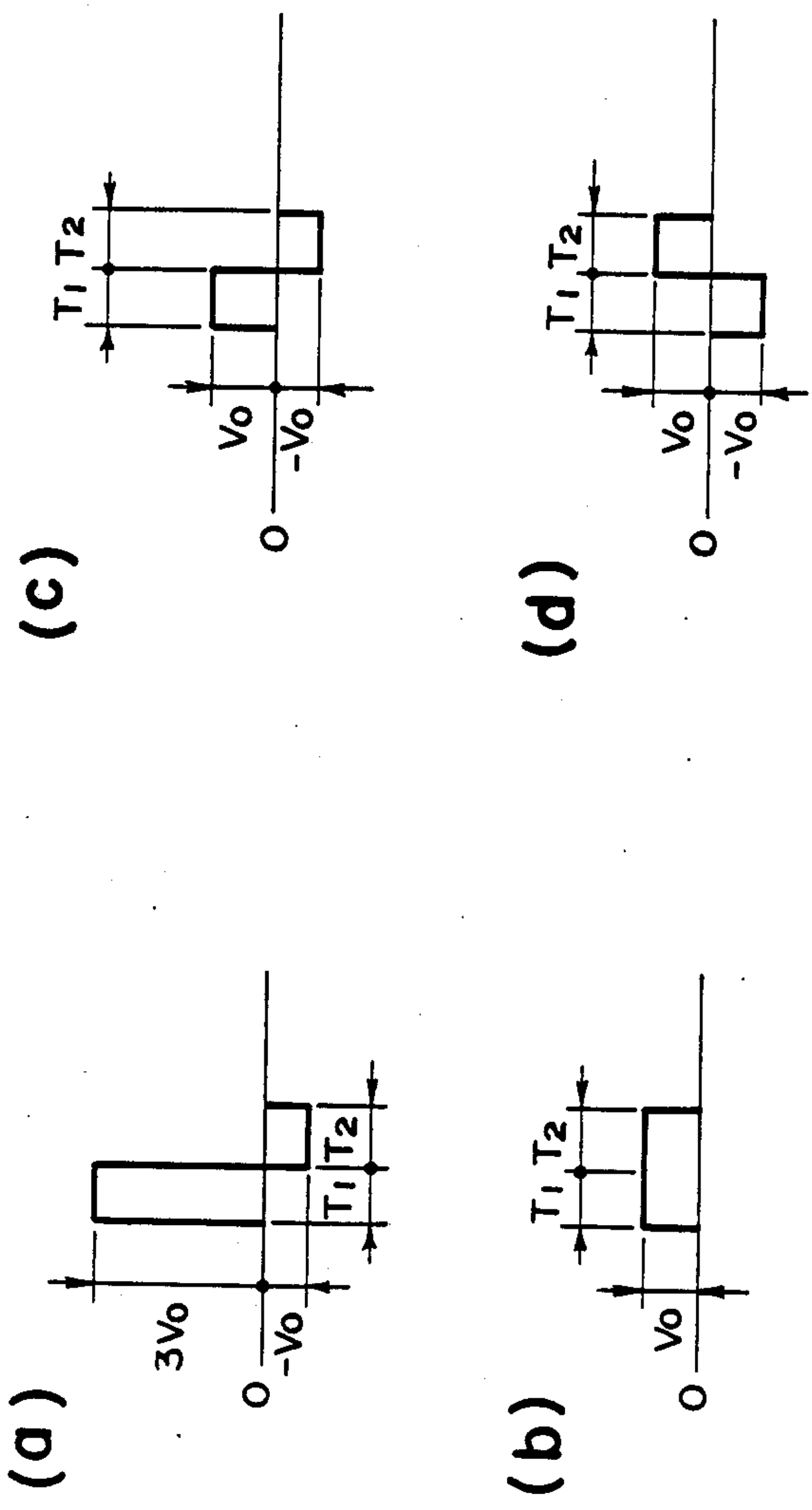
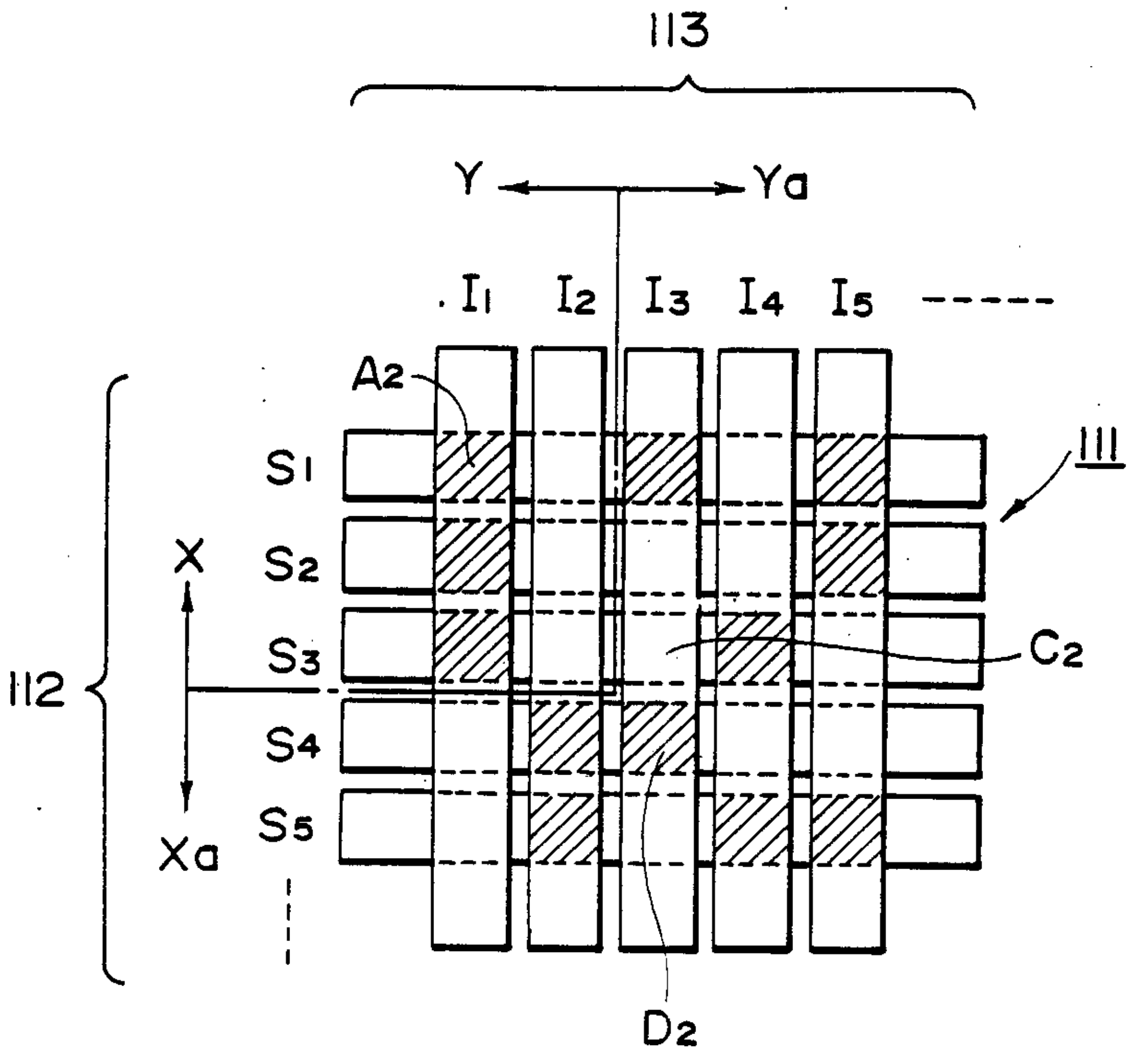


FIG. 11C



F I G. 11D

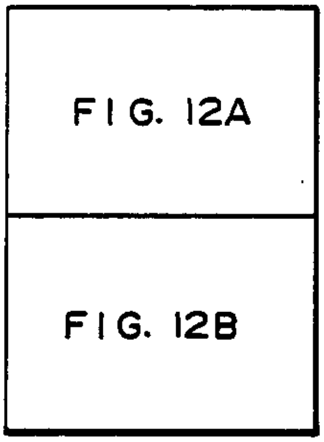


FIG. 12

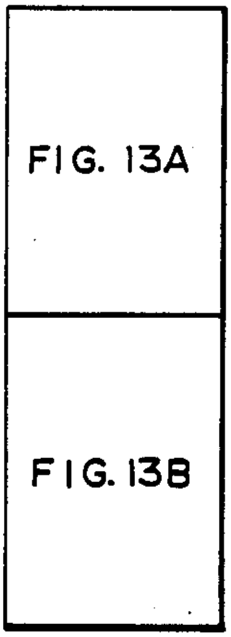


FIG. 13

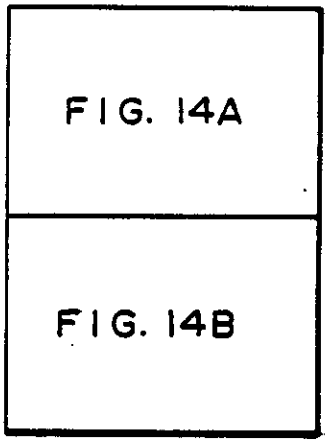


FIG. 14

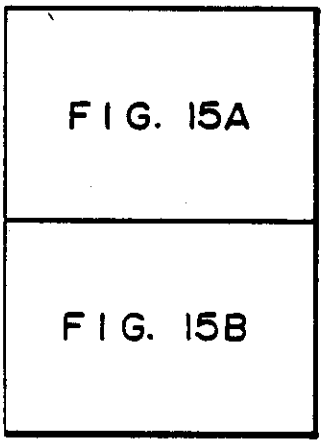


FIG. 15

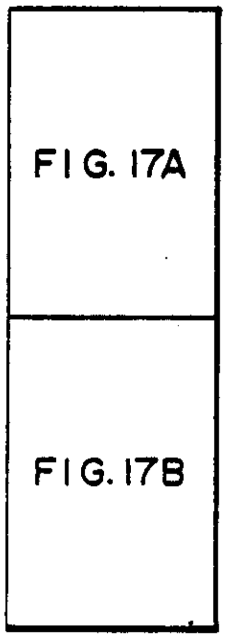
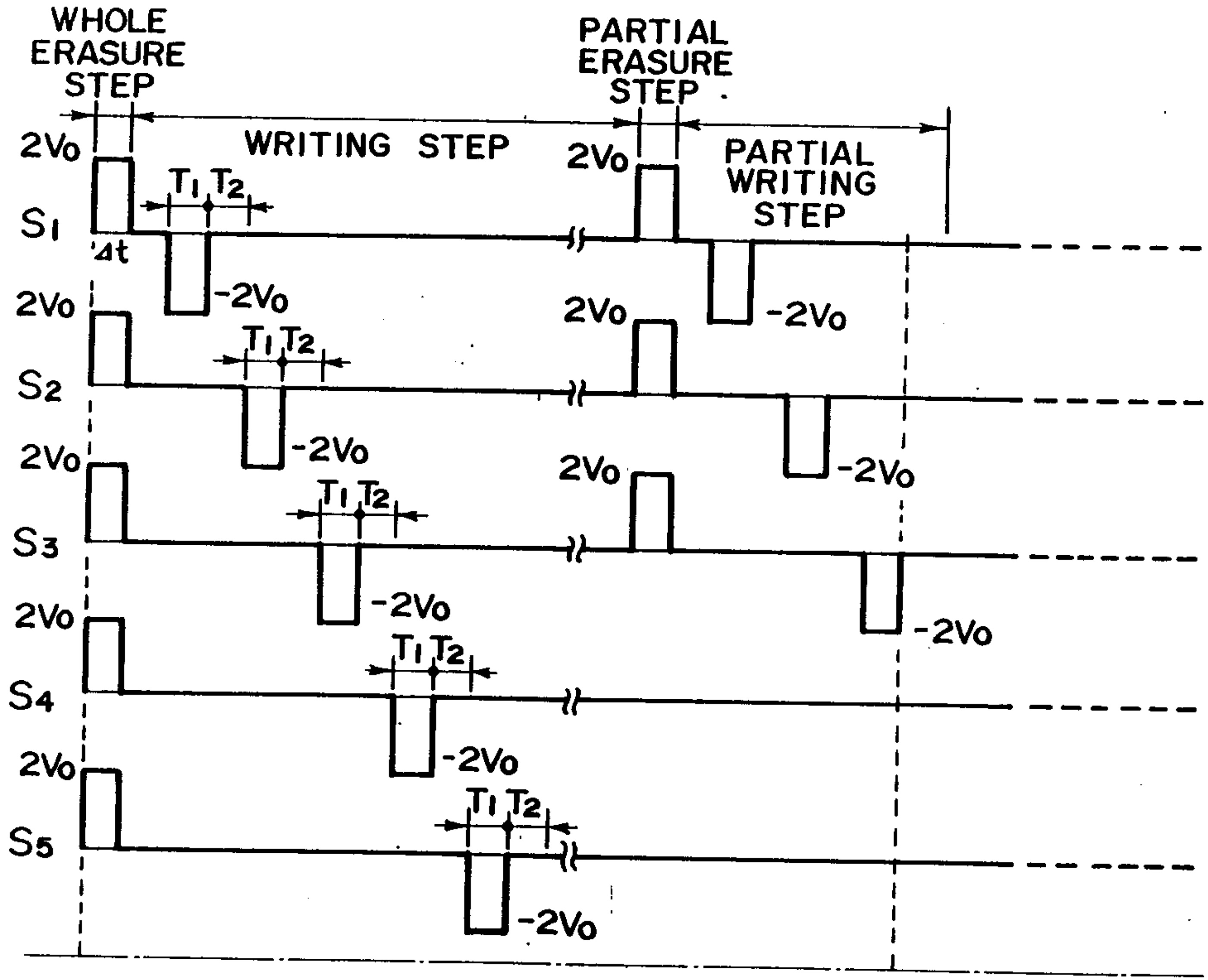


FIG. 17


WHOLE ERASURE STEP
WRITING STEP
PARTIAL ERASURE STEP
PARTIAL WRITING STEP
2Vo
-2Vo
S1
S2
S3
S4
S5
T1 T2
Δt

F I G. 12A

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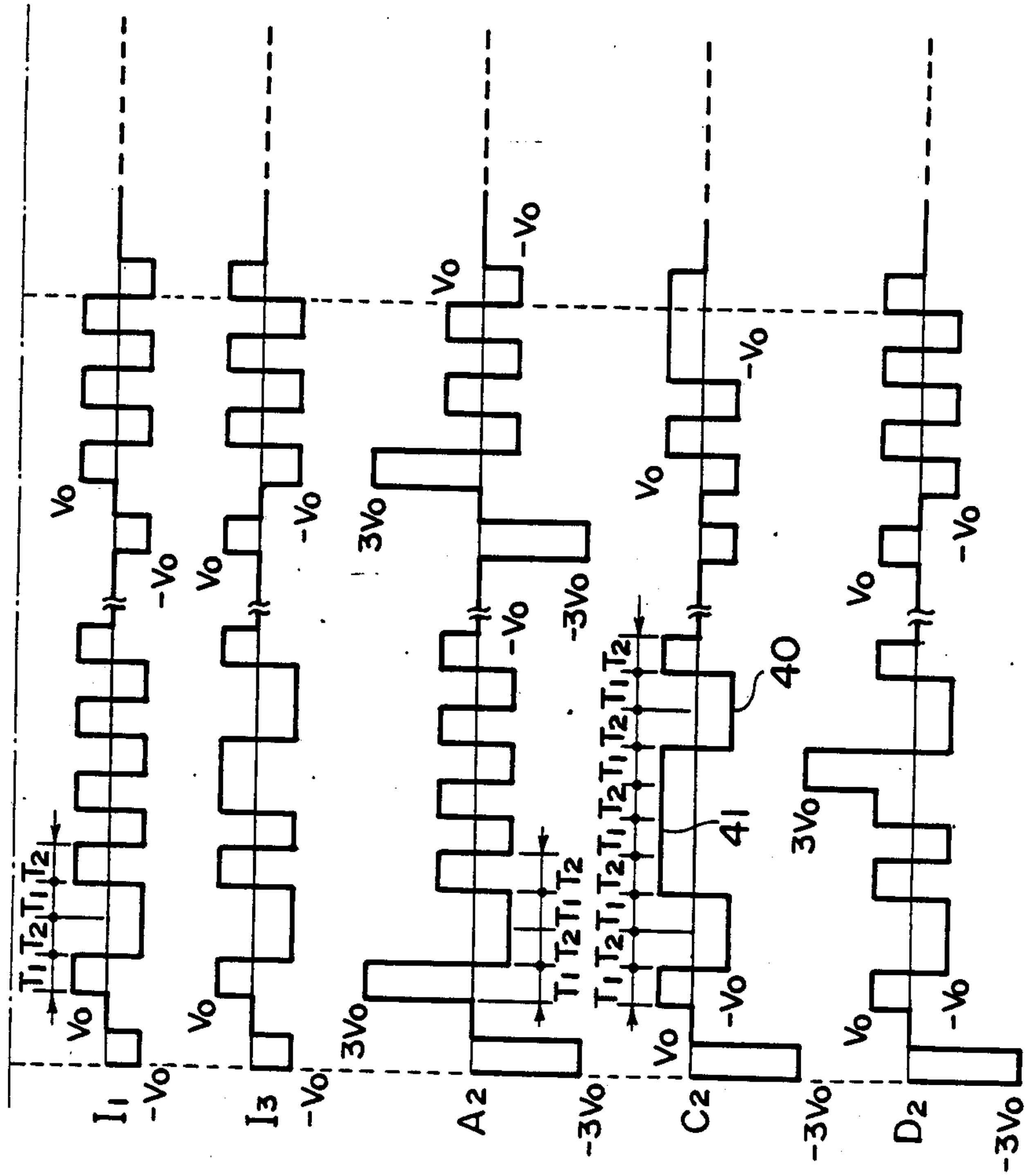
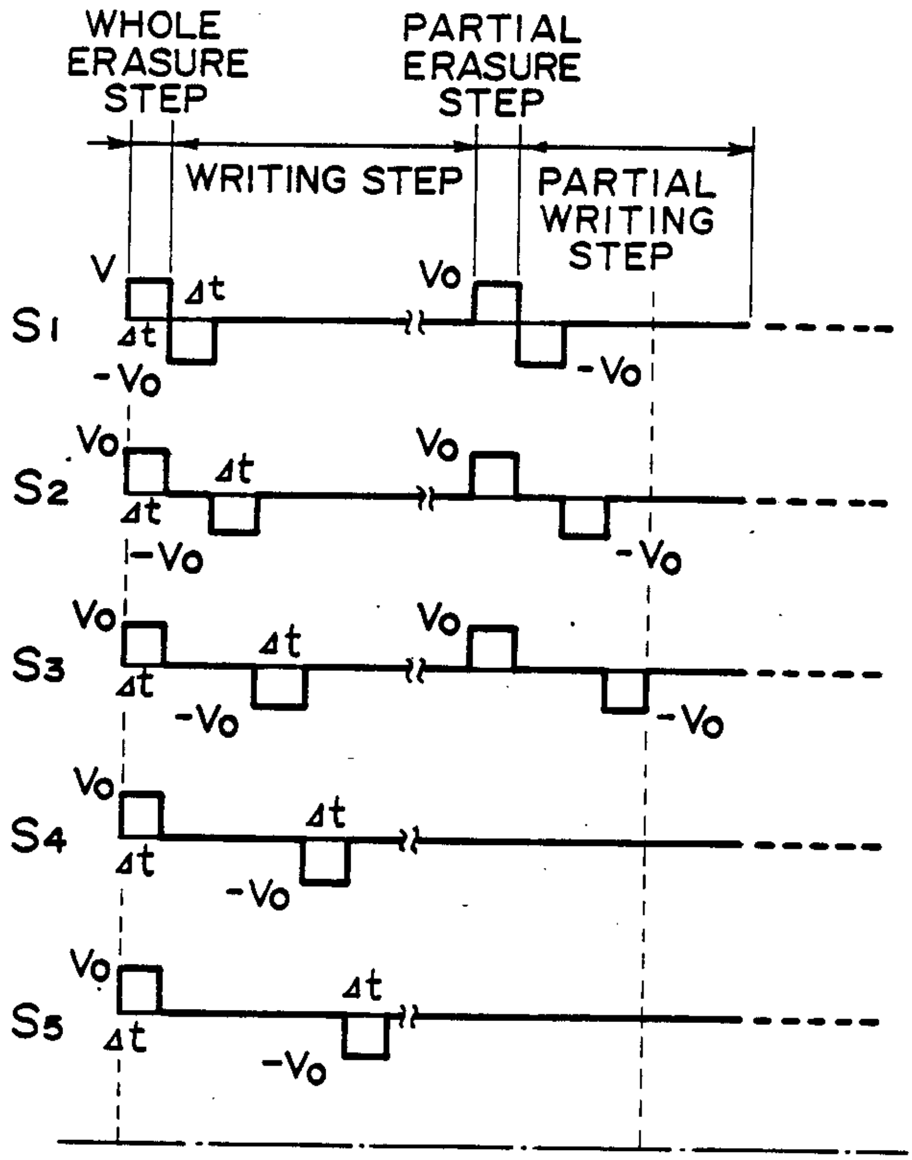
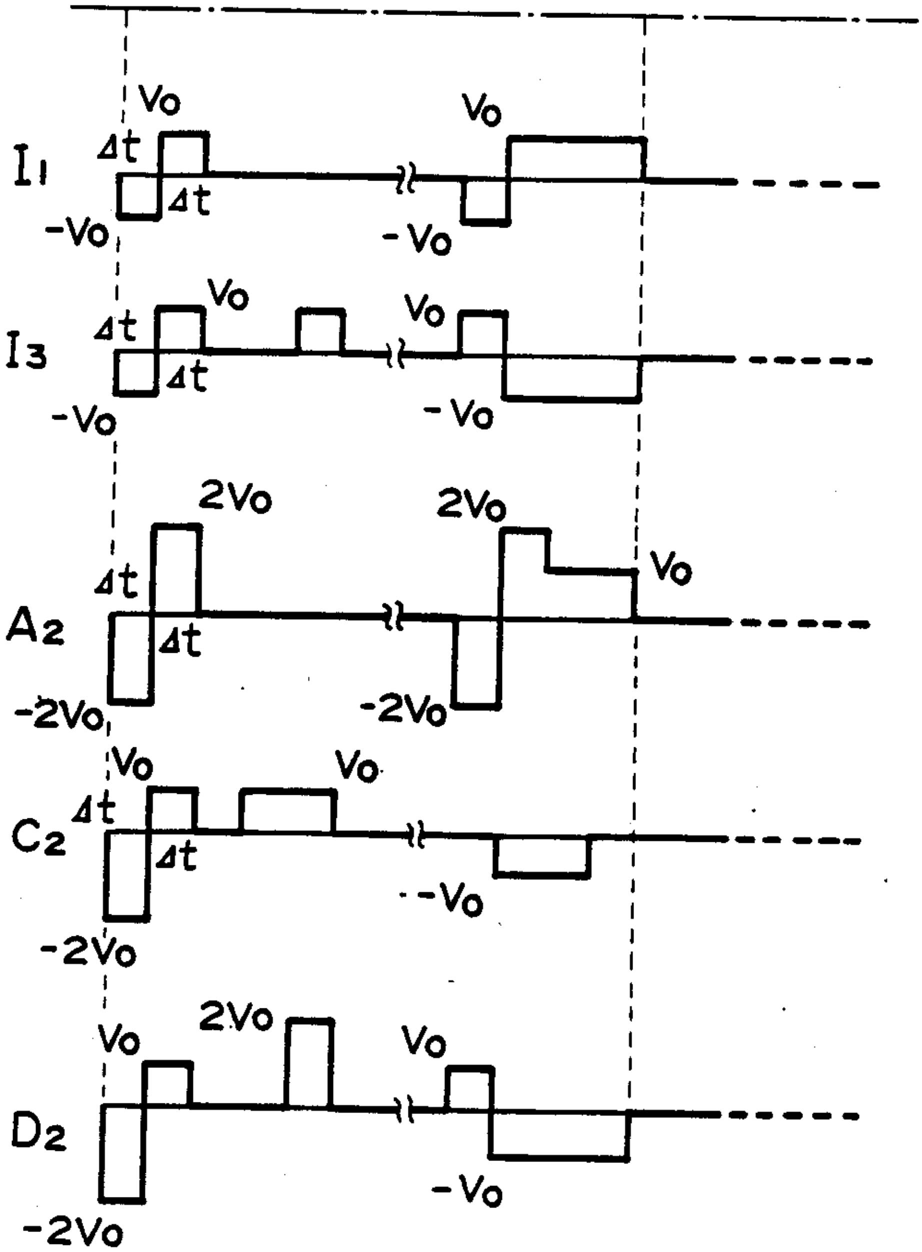


FIG. 12B


WHOLE ERASURE STEP
PARTIAL ERASURE STEP
WRITING STEP
PARTIAL WRITING STEP
V
Vo
Δt
-Vo
S1
S2
S3
S4
S5

F I G. 13A


I1
Vo
Δt
Δt
-Vo
Vo
-Vo
I3
Vo
Δt
Δt
-Vo
Vo
-Vo
A2
2Vo
Δt
Δt
-2Vo
2Vo
Vo
-2Vo
C2
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Δt
Δt
-2Vo
Vo
-Vo
D2
Vo
2Vo
-2Vo
Vo
-Vo

FIG. 13B

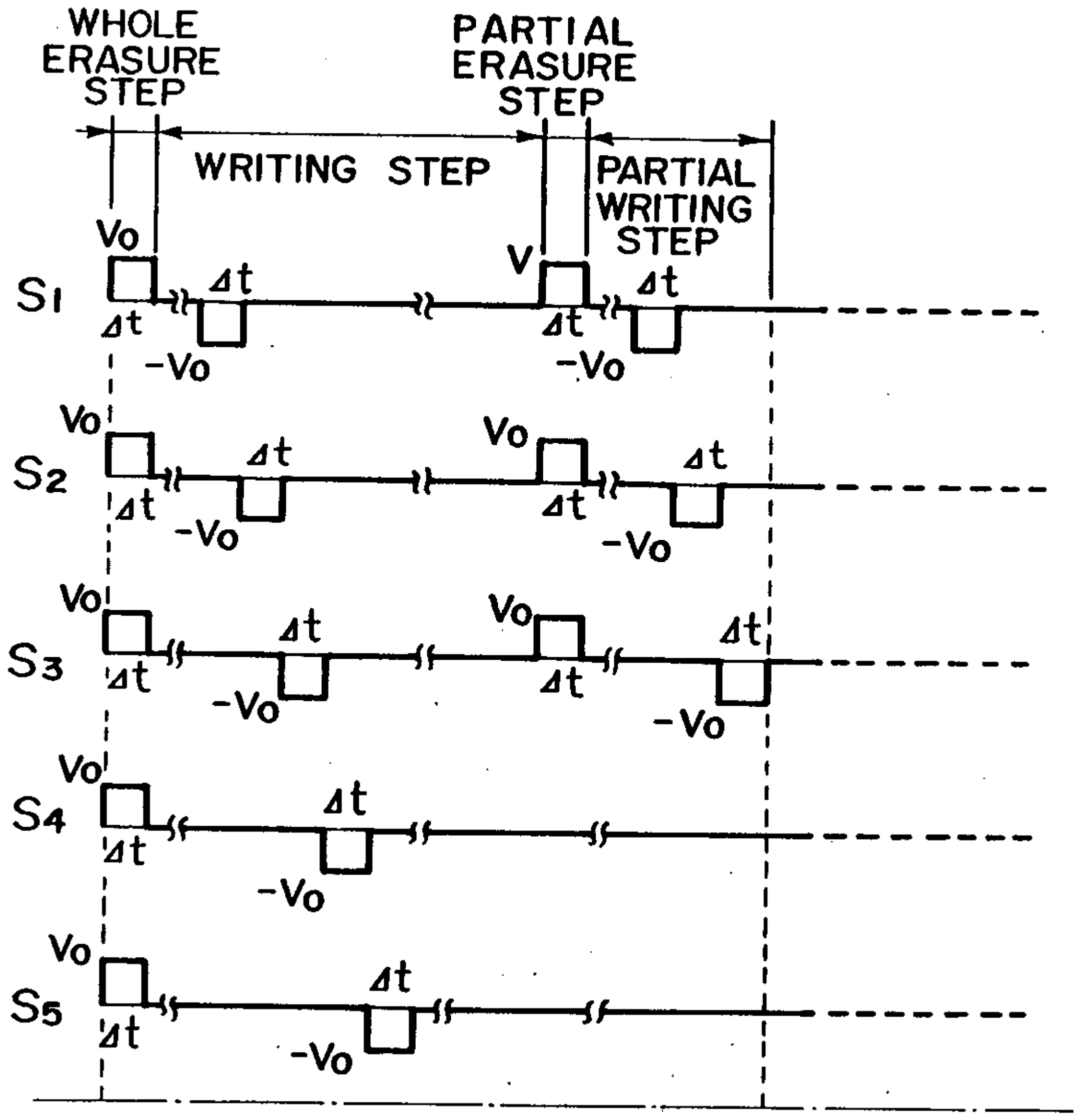
WHOLE ERASURE STEP
WRITING STEP
PARTIAL ERASURE STEP
PARTIAL WRITING STEP
S1
S2
S3
S4
S5
Vo
-Vo
V
Δt

FIG. 14A

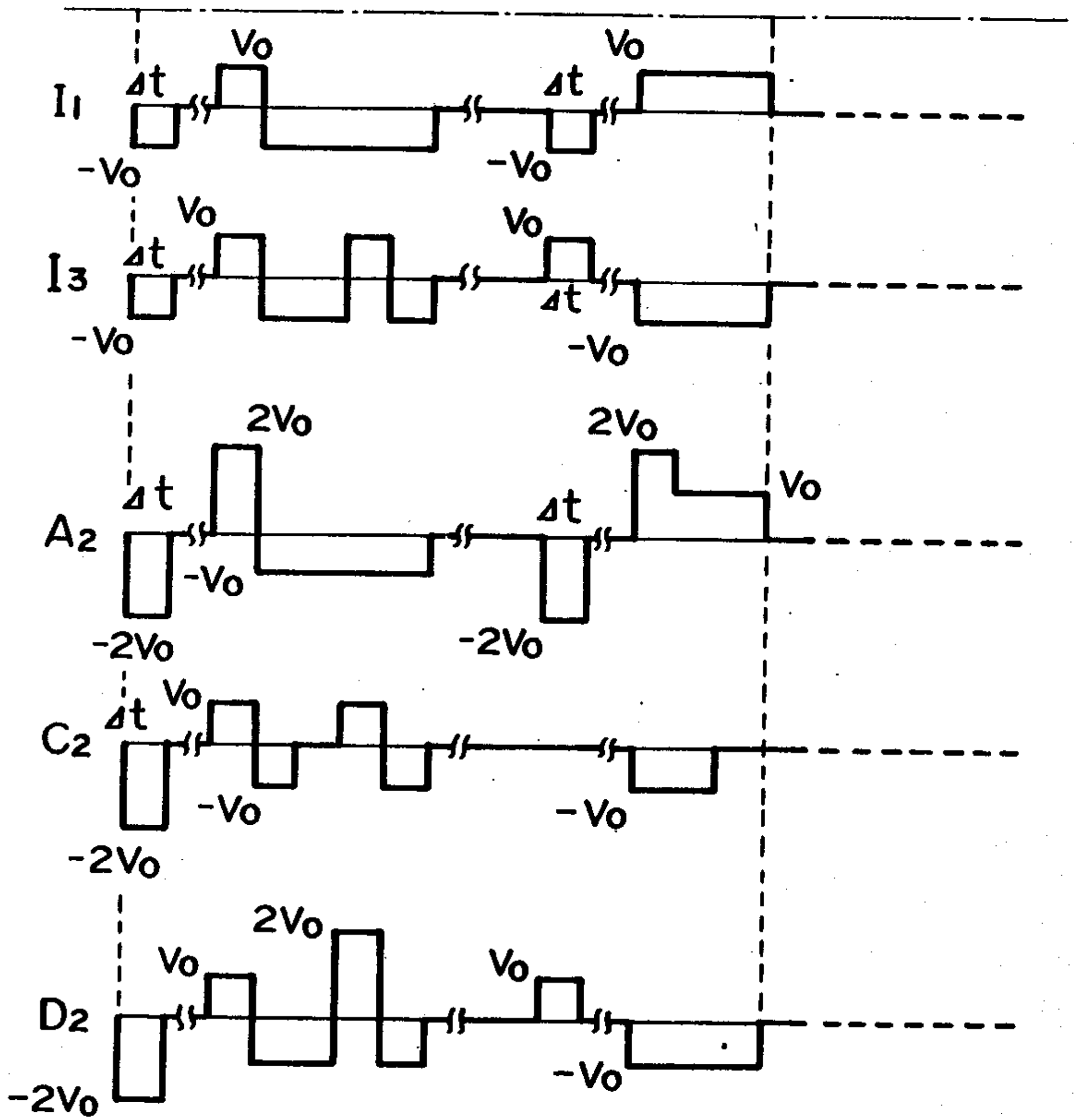

FIG. 14B

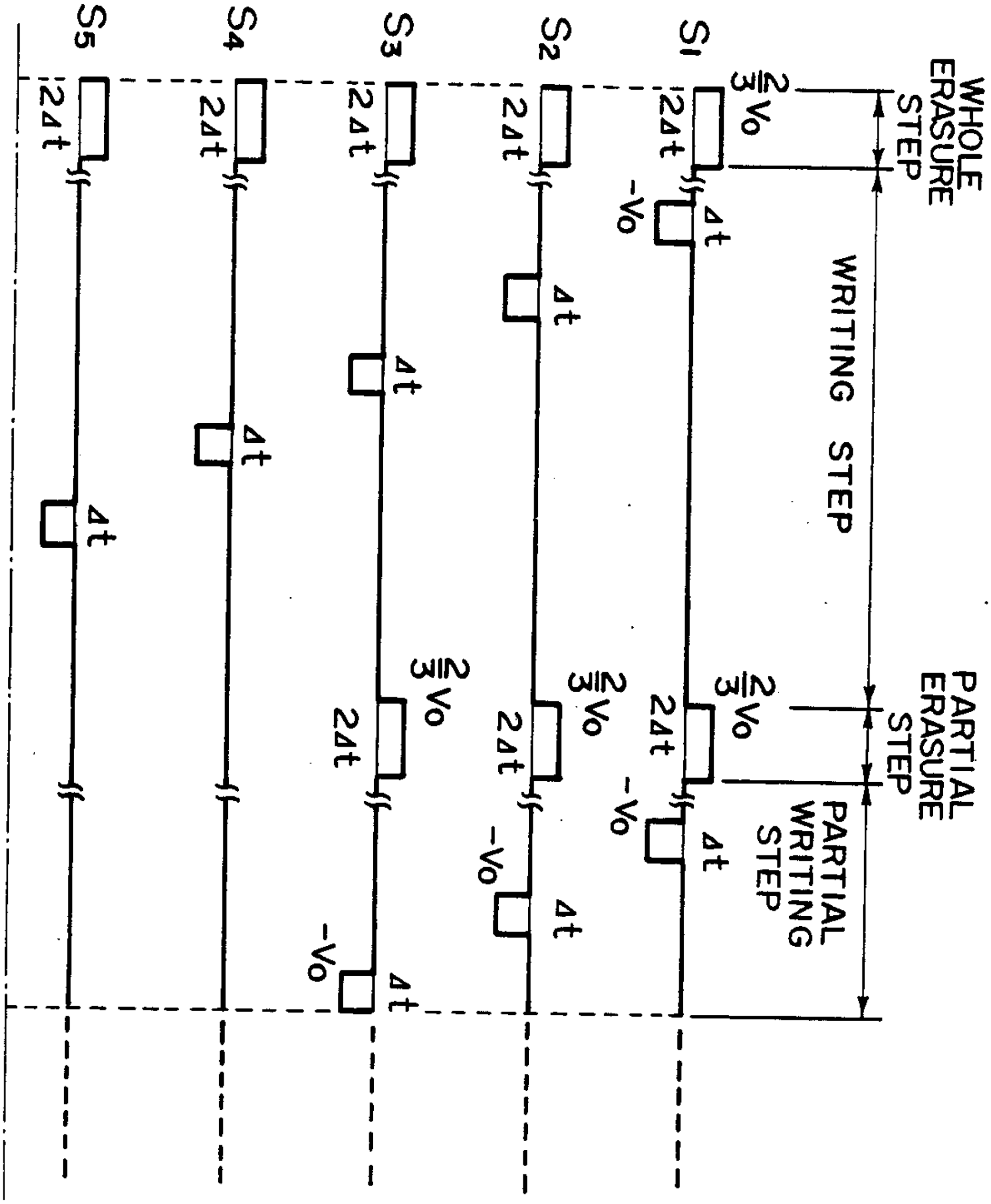
WHOLE ERASURE STEP
WRITING STEP
PARTIAL ERASURE STEP
PARTIAL WRITING STEP
S1
S2
S3
S4
S5
2/3 Vo
2Δt
Δt
-Vo

FIG. 15A

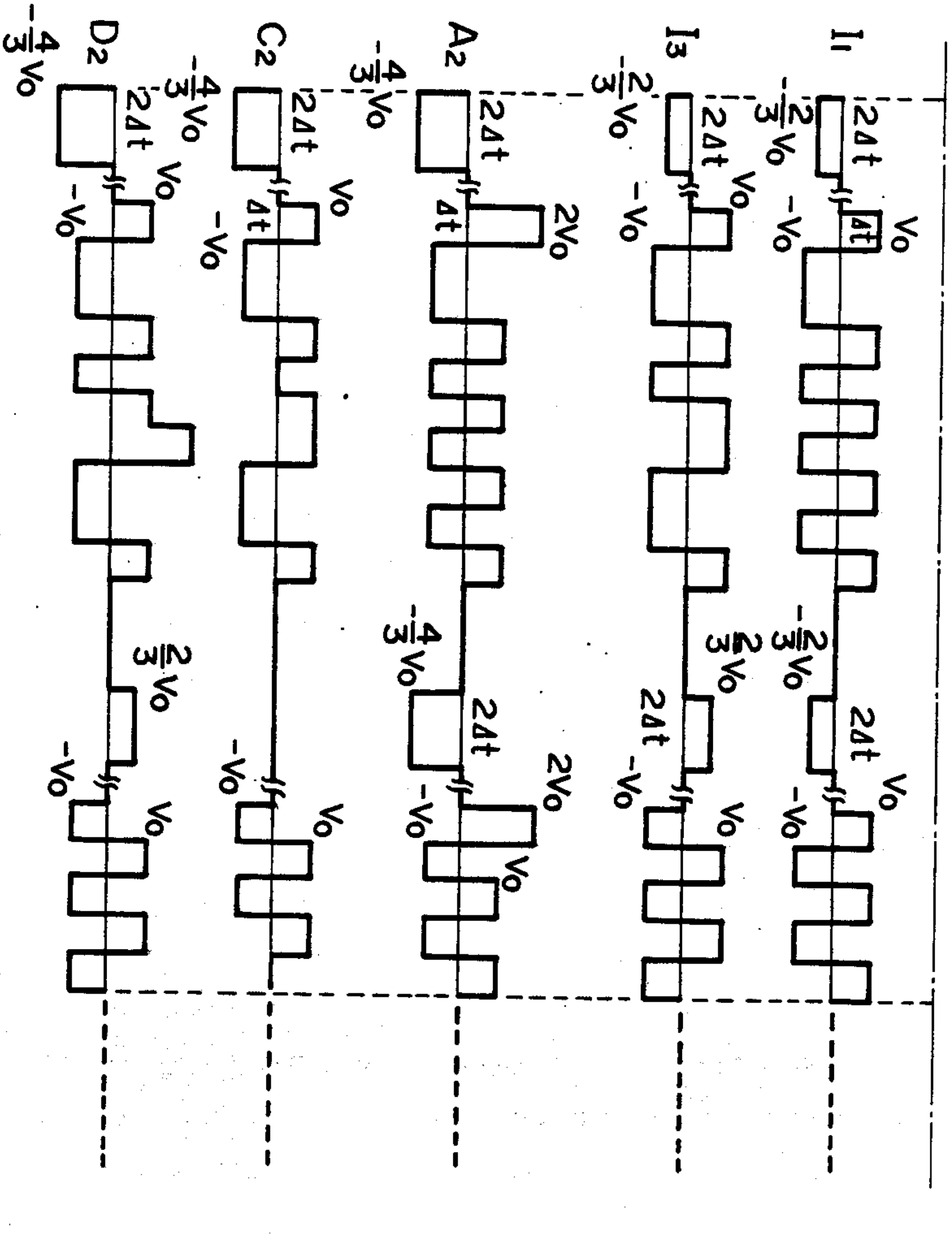

FIG. 15B

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OPTICAL MODULATION DEVICE AND DRIVING METHOD THEREFOR

BACKGROUND OF THE INVENTION

The present invention relates to an optical modulation device, e.g., a display device, an optical shutter array, etc., and to a driving method therefor.

Hitherto, liquid crystal display devices are well known, which comprise scanning lines (or electrodes) and data lines (or electrodes) arranged in a matrix manner, and a liquid crystal compound is filled between the lines to form a plurality of picture elements thereby to display images or information. These display devices employ a time-sharing driving method which comprises the steps of selectively applying scanning selection signals sequentially and cyclically to the scanning lines, and, in parallel therewith selectively applying predetermined information signals to the group of signal electrodes in synchronism with the scanning selection signals. However, these display devices and the driving method therefor have a serious drawback as will be described below.

Namely, the drawback is that it is difficult to obtain a high density of picture elements or a large image area. Because of relatively high response speed and low power dissipation, among prior art liquid crystals, most of liquid crystals which have been put into practice as display devices are TN (twisted nematic) type liquid crystals, as shown 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 the liquid crystals of this type, molecules of nematic liquid crystal which show positive dielectric anisotropy under no application of an electric field form a structure twisted in the thickness direction of liquid crystal layers (helical structure), and molecules of these liquid crystals are aligned or oriented parallel to each other in the surfaces of both electrodes. On the other hand, nematic liquid crystals which show positive dielectric anisotropy under application of an electric field are oriented or aligned in the direction of the electric field. Thus, they can cause optical modulation. When display devices of a matrix electrode arrangement are designed using liquid crystals of this type, a voltage higher than a threshold level required for aligning liquid crystal molecules in the direction perpendicular to electrode surfaces is applied to areas (selected points) where scanning lines and data lines are selected at a time, whereas a voltage is not applied to areas (non-selected points) where scanning lines and data lines are not selected and, accordingly, the liquid crystal molecules are stably aligned parallel to the electrode surfaces. When linear polarizers arranged in a cross-nicol relationship, i.e., with their polarizing axes being substantially perpendicular to each other, are arranged on the upper and lower sides of a liquid crystal cell thus formed, a light does not transmit at selected points while it transmits at non-selected points. Thus, the liquid crystal cell can function as an image device.

However, when a matrix electrode structure is constituted, a certain electric field is applied to regions where scanning lines are selected and data lines are not selected or regions where scanning lines are not selected and data lines are selected (which regions are so called "half-selected points"). If the difference between a voltage applied to the selected points and a voltage applied to the half-selected points is sufficiently large, and a voltage threshold level required for allowing liquid crystal molecules to be aligned or oriented perpendicular to an electric field is set to a value therebetween, the display device normally operates. However, in fact, according as the number (N) of scanning lines increases, a time (duty ratio) during which an effective electric field is applied to one selected point when a whole image area (corresponding to one frame) is scanned decreases with a ratio of 1/N. For this reason, the larger the number of scanning lines are, the smaller is the voltage difference as an effective value applied to a selected point and non-selected points when scanning is repeatedly effected. As a result, this leads to unavoidable drawbacks of lowering of image contrast or occurrence of crosstalk. These phenomena result in problems that cannot be essentially avoided, which apepar when a liquid crystal not having bistability (which shows a stable state where liquid crystal molecules are oriented or aligned in a horizontal direction with respect to electrode surfaces, but are oriented in a vertical direction only when an electric field is effectively applied) is driven, i.e., repeatedly scanned, by making use of time storage effect. To overcome these drawbacks, the voltage averaging method, the two-frequency driving method, the multiple matrix method, etc., has already been proposed. However, any method is not sufficient to overcome the above-mentioned drawbacks. As a result, it is the present state that the development of large image area or high packaging density in respect to display elements is delayed because of the fact that it is difficult to sufficiently increase the number of scanning lines.

Meanwhile, turning to the field of a printer, as means for obtaining a hard copy in response to input electric signals, a Laser Beam Printer (LBP) providing electric image signals to electrophotographic charging member in the form of lights is the most excellent in view of density of a picture element and a printing speed.

However, the LBP has drawbacks as follows:

1) It becomes large in apparatus size.

2) It has high speed mechanically movable parts such as a polygon scanner, resulting in noise and requirement for strict mechanical precision, etc.

In order to eliminate drawbacks stated above, a liquid crystal shutter-array is proposed as a device for changing electric signals to optical signals. When picture element signals are provided with a liquid crystal shutter-array, however, 2000 signal generators are required, for instance, for writing picture element signals into a length of 200 mm in a ratio of 10 dots/mm. Accordingly, in order to independently feed signals to respective signal generators, lead lines for feeding electric signals are required to be provided to all the respective signal generators, and the production has become difficult.

In view of the above, another attempt is made to apply one line of image signals in a time-sharing manner with signal generators divided into a plurality of lines.

With this attempt, signal feeding electrodes can be common to the plurality of signal generators, thereby enabling to remarkably decrease the number of lead wires. However, if the number (N) of lines is increased while using a liquid crystal showing no bistability as usually practiced, a signal "ON" time is substantially reduced to 1/N. This results in difficulties that light quantity obtained on a photoconductive member is decreased, and a crosstalk occurs.

SUMMARY OF THE INVENTION

According to one aspect of the present invention, there is provided a driving method for an optical modulation device having a plurality of electro-optical elements arranged in a matrix and comprising scanning lines, data lines spaced apart from and intersecting with the scanning lines, and a ferroelectric liquid crystal which assumes a first orientation state or a second orientation state depending on the direction of an electric field applied thereto interposed between the scanning lines and data lines, each of the intersections between the scanning lines and the data lines forming one of said electro-optical elements; said driving method comprising:

an erasure step wherein a voltage exceeding a first threshold voltage of the ferroelectric liquid crystal for causing the first orientation state of the ferroelectric liquid crystal is applied to the intersections of the scanning lines and the data lines;

a writing step wherein a scanning selection signal comprising a voltage of one polarity and a voltage of the other polarity with respect to the voltage of a non-selected scanning line is applied to a selected scanning line, an information selection signal providing a voltage exceeding a second threshold voltage of the ferroelectric liquid crystal for causing the second orientation state of the ferroelectric liquid crystal in combination with the voltage of one polarity of the scanning selection signal is applied to a selected data line, an information non-selection signal providing a voltage between the first and second threshold voltages of the ferroelectric liquid crystal in combination with the voltage of one polarity of the scanning selection signal is applied to other data lines, and an auxiliary signal for preventing unintentional inversion of the orientation states of the ferroelectric liquid crystal in combination with the voltage of the other polarity of the scanning selection signal is applied to the data lines.

According to another aspect of the present invention, there is provided an optical modulation device having a plurality of electro-optical elements arranged in a matrix and comprising scanning lines, data lines spaced apart from and intersecting with the scanning lines and a ferroelectric liquid crystal which assumes a first orientation state or a second orientation state depending on the direction of an electric field applied thereto interposed between the scanning lines and the data lines, each of the intersections between the scanning lines and the data lines forming one of said electro-optical elements; said optical modulation device comprising:

an erasure means by which a voltage exceeding a first threshold voltage of the ferroelectric liquid crystal for causing the first orientation state of the ferroelectric liquid crystal is applied to the intersections of the scanning lines and the data lines;

a writing means by which a scanning selection signal comprising a voltage of one polarity and a voltage of the other polarity with respect to the voltage of a non-selected scanning line is applied to a selected scanning line, an information selection signal providing a voltage exceeding a second threshold voltage of the ferroelectric liquid crystal for causing the second orientation state of the ferroelectric liquid crystal in combination with the voltage of one polarity of the scanning selection signal is applied to a selected data line, an information non-selection signal providing a voltage between the first and second threshold voltages of the ferroelectric liquid crystal in combination with the voltage of one polarity of the scanning selection signal is applied to other data lines, and an auxiliary signal for preventing unintentional inversion of the orientation states of the ferroelectric liquid crystal in combination with the voltage of the other polarity of the scanning selection signal is applied to the data lines.

According to a further aspect of the present invention, there is provided a driving method for an optical modulation device having a plurality of electro-optical elements arranged in a matrix and comprising scanning lines, data lines spaced apart from and intersecting with the scanning lines, and a ferroelectric liquid crystal which assumes a first orientation state or a second orientation state depending on the direction of an electric field applied thereto interposed between the scanning lines and the data lines, each of the intersections between the scanning lines and the data lines forming one of said electro-optical elements; said driving method comprising:

a step of forming an image area comprising electro-optical elements wherein the ferroelectric liquid crystal assumes the first orientation state formed by application of a voltage of one polarity exceeding a first threshold voltage of the ferroelectric liquid crystal and electro-optical elements wherein the ferroelectric liquid crystal assumes the second orientation state formed by application of a voltage of the other polarity exceeding a second threshold voltage of the ferroelectric liquid crystal, a rewriting region being defined in the image area;

a first step wherein, in the rewriting region, a voltage of one polarity exceeding the first threshold voltage of the ferroelectric liquid crystal is applied to the intersections of a scanning line and the data lines; and

a second step wherein a scanning selection signal is applied to a scanning line in the rewriting region, an information selection signal providing a voltage of the other polarity exceeding the second threshold voltage of the ferroelectric liquid crystal in combination with the scanning selection signal and an auxiliary signal are applied to a selected data line in the rewriting region, and a voltage of the same voltage level as a scanning non-selection signal applied to a non-selected scanning line in the rewriting region is applied to scanning lines outside the rewriting region;

the auxiliary signal providing an inversion preventing voltage in combination with the scanning non-selection signal applied to a non-selected scanning line before the application period of a voltage of a particular polarity reaches a period beyond which the first or second orientation state of an electro-optical element on the non-selected scanning line is unintentionally inverted due to said voltage of said particular polarity and less than the relevant threshold voltage, the inversion preventing voltage being a zero voltage or having a polarity opposite to said particular polarity.

According to yet another aspect of the present invention, an optical modulation device having a plurality of electro-optical elements arranged in a matrix and comprising scanning lines, data lines spaced apart from and intersecting with the scanning lines, and a ferroelectric liquid crystal which assumes a first orientation state or a second orientation state depending on the direction of an electric field applied thereto interposed between the scanning lines and the data lines, each of the intersections between the scanning lines and the data lines forming one of said electro-optical elements; said optical modulation device comprising means for effecting:

a step of forming an image area comprising electro-optical elements wherein the ferroelectric liquid crystal assumes the first orientation state formed by application of a voltage of one polarity exceeding a first threshold voltage of the ferroelectric liquid crystal and electro-optical elements wherein the ferroelectric liquid crystal assumes the second orientation state formed by application of a voltage of the other polarity exceeding a second threshold voltage of the ferroelectric liquid crystal, a rewriting region being defined in the image area;

a first step wherein, in the rewriting region, a voltage of one polarity exceeding the first threshold voltage of the ferroelectric liquid crystal is applied to the intersections of a scanning line and the data lines; and

a second step wherein a scanning selection signal is applied to a scanning line in the rewriting region, an information selection signal providing a voltage of the other polarity exceeding the second threshold voltage of the ferroelectric liquid crystal in combination with the scanning selection signal and an auxiliary signal are applied to a selected data line in the rewriting region, and a voltage of the same voltage level as a scanning non-selection signal applied to a non-selected scanning line in the rewriting region is applied to scanning lines outside the rewriting region;

the auxiliary signal providing an inversion preventing voltage in combination with the scanning non-selection signal applied to a non-selected scanning line before the application period of a voltage of a particular polarity reaches a period beyond which the first or second orientation state of an electro-optical element on the non-selected scanning line is unintentionally inverted due to said voltage of said particular polarity and less than the relevant threshold voltage, the inversion preventing voltage being a zero voltage or having a polarity opposite to said particular polarity.

According to a yet further aspect of the present invention there is provided a driving method for an optical modulation device having a plurality of electro-optical elements arranged in the form of a matrix and comprising scanning lines, data lines spaced apart from and intersecting with the scanning lines, and a ferroelectric liquid crystal interposed between the scanning lines and the data lines, each of the intersections between the scanning lines and the data lines forming one of said electro-optical elements; said driving method comprising:

a first step wherein a voltage exceeding a first threshold voltage of the ferroelectric liquid crystal for providing a first orientation state of the ferroelectric liquid crystal is applied to the intersections of the scanning lines and the data lines; and

a second step wherein a scanning selection signal is applied to a scanning line, and information selection signal providing a voltage exeeding a second threshold voltage of the ferroelectric liquid crystal for providing a second orientation state of the ferroelectric liquid crystal in combination with the scanning selection signal and an auxiliary signal are applied to a selected data line in the same time period as the scanning selection signal;

said auxiliary signal providing an inversion preventing voltage in combination with a voltage applied to a non-selected scanning line before the application period of a voltage of a particular polarity reaches a period beyond which the first or second orientation state of an electro-optical element on the non-selected scanning line is unintentionally inverted due to said voltage of said particular polarity and less than the relevant threshold voltage, the inversion preventing voltage having a polarity opposite to said particular polarity;

the voltage signals applied to the scanning lines and

the data lines in the first step having polarities opposite to those of the scanning selection signal and the information selection signal, respectively, applied in the second step with respect to the voltage applied to the non-selected scanning line;
the voltage signals applied to the scanning lines and the data lines in the first step having mutually opposite polarities with respect to the voltage applied to the non-selected scanning line.

According to another aspect of the present invention, there is provided an optical modulation device having a plurality of electro-optical elements arranged in the form of a matrix and comprising scanning lines, data lines spaced apart from and intersecting with the scanning lines, and a ferroelectric liquid crystal interposed between the scanning lines and the data lines, each of the intersections between the scanning lines and the data lines forming one of said electro-optical elements; said optical modulation device comprising means for effecting:
a first step wherein a voltage exceeding a first threshold voltage of the ferroelectric liquid crystal for providing a first orientation state of the ferroelectric liquid crystal is applied to the intersections of the scanning lines and the data

lines; and

a second step wherein a scanning selection signal is applied to a scanning line, and information selection signal providing a voltage exceeding a second threshold voltage of the ferroelectric liquid crystal for providing a second orientation state of the ferroelectric liquid crystal in combination with the scanning selection signal and an auxiliary signal are applied to a selected data line in the same time period as the scanning selection signal;

said auxiliary signal providing an inversion preventing voltage in combination with a voltage applied to a non-selected scanning line before the application period of a voltage of a particular polarity reaches a period beyond which the first or second orientation state of an electro-optical element on the non-selected scanning line is unintentionally inverted due to said voltage of said particular polarity and less than the relevant threshold voltage, the inversion preventing voltage having a polarity opposite to said particular polarity;

the voltage signals applied to the scanning lines and the data lines in the first step having polarities opposite to those of the scanning selection signal and the information selection signal, respectively, applied in the second step with respect to the voltage applied to the non-selected scanning line;

the voltage signals applied to the scanning lines and the data lines in the first step having mutually opposite polarities with respect to the voltage applied to the non-selected scanning line.

There follows, by way of example, a description with reference to the drawings of specific embodiments of the present invention.

BRIEF DESCRIPTION OF THE DRAWINGS

Figures 1 and 2 are schematic perspective views illustrating the basic operation principle of a liquid crystal device used in the present invention,

Figure 3A is a plan view of an electrode arrangement used in the present invention,

Figures 3B (a) - (d) illustrate waveforms of electric signals applied to electrodes, but not forming an embodiment of the invention,

Figures 3C (a) - (d) illustrate voltage waveforms applied to picture elements, but not forming an embodiment of the invention,

Figures 4A and 4B, in combination, illustrate voltage waveforms applied in time series, but not forming an embodiment of the invention,

Figures 5A (a) - (d) illustrate waveforms of electric signals applied to electrodes in an embodiment of the invention,

Figures 5B (a) - (d) illustrate voltage waveforms applied across picture elements by the signals of Figures 5A (a) to 5A (d).

Figures 6A to 10A in combination with Figures 6B to 10B, respectively, illustrate different examples of voltage waveforms applied in time series, Figures 6, 7 and 10 forming embodiments of the invention, but

Figures 8 and 9 not forming embodiments of the invention.

Figures 11A and 11D are plan views respectively showing an electrode arrangement used in a different embodiment of the driving method according to the present invention,

Figures 11B(a) - (d) illustrate waveforms of electric signals applied to electrodes,

Figures 11C(a) - (d) illustrate voltage waveforms applied to picture elements, and

Figures 12A to 15A in combination with Figures 12B to 15B, respectively, illustrate still different examples of voltage waveforms applied in time series, in which Figures 12A, 12B, 15A and 15B form embodiments of the invention, but Figures 13A, 13B, 14A and 14B do not.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

As an optical modulation material used in a driving method according to the present invention, a ferro-electric liquid crystal, material which shows either a first optically stable state or a second optically stable state depending upon an electric field applied thereto, i.e., has bistability with respect to the applied electric field,

~~particularly a liquid crystal having the above-mentioned property, may be~~ is used.

Preferable liquid crystals having bistability which can be used in the driving method according to the present invention are chiral smectic C (SmC*)- or H (SmH*)-phase liquid crystals having ferroelectricity. In addition, liquid crystals showing chiral smectic I phase (SmI*), J phase (SmJ*), G phase (SmG*), F phase (SmF*) or K phase (SmK*) may also be used. These ferroelectric liquid crystals are described in, e.g., "LE JOURNAL DE PHYSIQUE LETTERS" 36 (L-69), 1975 "Ferroelectric Liquid Crystals"; "Applied Physics Letters" 36 (11) 1980, "Submicro Second Bistable Electrooptic Switching in Liquid Crystals", "Solid State Physics" 16 (141), 1981 "Liquid Crystal", etc. Ferroelectric liquid crystals disclosed in these publications may be used in the present invention.

More particularly, examples of ferroelectric liquid crystal compound usable in the method according to the present invention include decyloxybenzylidene-p'-amino-2-methylbutyl cinnamate (DOBAMBC), hexyloxybenzylidene-p'-amino-2-chloropropyl cinnamate (HOBACPC), 4-o-(2-methyl)-butylresorcilidene-4'-octylaniline (MBRA8), etc.

When a device is constituted using these materials, the device may be supported with a block of copper, etc., in which a heater is embedded in order to realize a temperature condition where the liquid crystal compounds assume a smectic phase.

Referring to Figure 1, there is schematically shown an example of a ferroelectric liquid crystal cell for explanation of the operation thereof. Reference numerals 11 and 11a denote base plates (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*- or SmH*-phase in which liquid crystal molecular layers 12 are oriented perpendicular to surfaces of the glass plates is hermetically disposed therebetween. A full line 13 shows liquid crystal molecules. Each liquid crystal molecule 13 has a dipole moment ($P\perp$) 14 in a direction perpendicular to the axis thereof. When a voltage higher than a certain threshold level is applied between electrodes formed on the base plates 11 and 11a, a helical structure of the liquid crystal molecule 13 is loosened a unwound to change the alignment direction of respective liquid crystal molecules 13 so that the dipole moments ($P\perp$) 14 are all directed in the direction of the electric field. The liquid crystal molecules 13 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 arranged in a cross nicol relationship, i.e., with their polarizing directions 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 loosened even in the absence of an electric field whereby the dipole moment assumes either of the two states, i.e., P in an upper direction 24 or Pa in a lower direction 24a as shown in Figure 2. When electric field E or Ea higher than a certain threshold level and different from each other in polarity as shown in Figure 2 is applied to a cell having the above-mentioned characteristics, the dipole moment is directed either in the upper direction 24 or in the lower direction 24a depending on the vector of the electric field E or Ea. In correspondence with this, the liquid crystal molecules are oriented in either of a first stable state 23 and a second stable state 23a.

When the above-mentioned ferroelectric liquid crystal is used as an optical modulation element, it is possible 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 2. When the electric field E is applied to the liquid crystal molecules, they are oriented in the first stable state 23. This state is kept stable even if the electric field is removed. On the other hand, when the electric field Ea of which direction is opposite to that of the electric field E is applied thereto, the liquid crystal molecules are oriented to the second stable state 23a, whereby the directions of molecules are changed. This state is also kept stable even if the electric field is removed. Further, as long as the magnitude of the electric field E being applied is not above a certain threshold value, the liquid crystal 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. A liquid crystal-electrooptical device having a matrix electrode structure in which the ferroelectric liquid crystal of this kind is used is proposed, e.g., in the specification of U.S. Patent No. 4367924 by Clark and Lagerwall.

A driving method which does not employ the present invention is explained with reference to Figure 3.

Figure 3A schematically shows a cell 31 having picture elements arranged in a matrix which comprise scanning lines (scanning electrodes), data lines (signal electrodes) and a bistable optical modulation material interposed therebetween. Reference numeral 32 denotes data lines. For the brevity of explanation, a case where two state signals of "white" and "black" are displayed is explained. It is assumed that hatched picture elements correspond to "black" and the other picture elements correspond to "white" in Figure 3A. First, in order to make a picture uniformly "white" (this step is called an "erasure step"), the bistable optical modulation material may be uniformly oriented to the first stable state. This can be effected by applying a predetermined voltage pulse signal (e.g., voltage: $+2V_0$, time width: Δt) to all the scanning lines and applying a predetermined pulse signal (e.g., $-V_0$, Δt) to all the data lines. In the erasure step, an electric signal of polarity opposite to that of a scanning selection signal in the writing step described hereinbelow is applied to the scanning lines, and an electric signal of a polarity opposite to that of an information selection signal (writing signal) in the writing step is applied to the data line, in phase with each other.

Figure 3B(a) and 3B(b) show an electric signal (scanning selection signal) applied to a selected scanning line and an electric signal (scanning non-selection signal) applied to the other scanning lines (non-selected scanning lines), respectively. Figures 3B(c) and 3B(d) show an electric signal (information selection signal; V_0 applied at phase T_1) applied to a selected (referred to as "black") data line and an electric signal (information non-selection signal; $-V_0$ at phase T_1) applied to a non-selected (referred to as "white") data line, respectively. In the Figures 3B(a) - 3B(d), the abscissa represents time, and the ordinate a voltage, respectively. T_1 and T_2 in the figures represent a phase for applying an information signal (and a scanning signal) and a phase for applying an auxiliary signal. This example shows a case where $T_1 = T_2 = \Delta t$.

The scanning lines 32 are selected sequentially. It is assumed herein that a threshold voltage for providing the first stable state (white) of the bistable liquid crystal at an application time of Δt be $-V_{th2}$, and a threshold voltage for providing the second stable state at an application time of Δt be V_{th1}. Then, the electric signal applied to the selected scanning line comprises voltages of $-2V_0$ at phase (time) T_1 and 0 at phase (time) T_2 as shown in Figure 3B(a). The other scanning lines are placed in grounded condition as shown in Figure 3B(b) and the electric signal is 0. On the other hand, the electric signal applied to the selected data line comprises V_0 at phase T_1 and $-V_0$ at phase T_2 as shown in Figure 3B(c), and the electric signal applied to the non-selected data line comprises $-V_0$ at phase T_1 and $+V_0$ at phase T_2 as shown in Figure 3B(d). In this instance, the voltage V_0 is set to a desired value which satisfies $V_0 < V_{th1} < 3V_0$ and $-V_0 > -V_{th2} > -3V_0$.

Voltage waveforms applied to respective picture elements when the above-mentioned electric signals are given are shown in Figures 3C. Figures 3C(a) and 3C(b) show voltage waveforms applied to picture elements where "black" and "white" are displayed, respectively, on the selected scanning line. Figures 3C(c) and 3C(d) respectively show voltage waveforms applied to picture elements on the non-selected scanning lines.

At phase T_1, on the scanning line to which a scanning selection signal $-2V_0$ is applied, an information signal $+V_0$ is applied to a picture element where "black" is to be displayed and, therefore, a voltage $3V_0$ exceeding the threshold voltage V_{th1} is applied to the picture element, where the bistable liquid crystal is oriented to the second optically stable state. Thus, the picture element is written in "black" (writing step). On the same scanning line, the voltage applied to picture elements where "white" is to be displayed is a voltage V_0 which does not exceed the threshold voltage V_{th1}, and accordingly the picture element remains in the first optically stable state, thus displaying "white".

On the other hand, on the non-selected scanning lines, the voltage applied to all the picture elements is $\pm V$ or 0, each not exceeding the threshold voltage. Accordingly, the liquid crystal at the respective picture elements retains its orientation which has been obtained when the picture elements have been last scanned. In other words, after the whole picture elements have been oriented to one optically stable state ("white"), when one scanning line is selected, signals are written in one line of picture elements at the first phase T_1 and the written signal or display states are retained even after steps for writing one frame is finished.

Figure 4(combination of Figures 4A and 4B) shows an example of the above-mentioned driving signals in time series. S_1 to S_5 represent electric signals applied to scanning lines; I_1 and I_3 represent electric signals applied to data lines; and A_1 and C_1 represent voltage waveforms applied to picture elements A_1 and C_1, respectively, shown in Figure 3A.

Microscopic mechanism of switching due to electric field of a ferroelectric liquid crystal having bistability has not 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 such a weak field (corresponding to a voltage below V_{th} in the previous example) that the stable state of the 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 kind of the liquid crystal, but have not clarified the effects quantitatively. We have confirmed a tendency that a monoaxial treatment of the base plate 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 direction of electric field is prevented from being applied to the liquid crystal for a long time.

The phase T_2 in the driving method described above is a phase for obviating a situation where a unidirectional weak electric field is continuously applied.

As shown in Figures 3B(c) and 3B(d), a signal with a polarity opposite to that of the information signal (Figure 3B(c) corresponds to "black", Figure 3B(d) to "white") applied at phase T_1 is applied to the data line at phase T_2. In a case where a pattern shown in Figure 3A is intended to be displayed, for example, by a driving method not having such phase T_2, picture element A is made "black" on scanning of the scanning electrode S_1, but it is highly possible that the picture element A will be switched sometime to "white" because an electric signal or voltage of $-V_0$ is continuously applied to the signal electrode I, during the steps for scanning of the scanning electrode S_2 and so on and the voltage is continuously applied to the picture element A as it is.

The whole picture is once uniformly rendered "white", and then "black" is written into picture elements corresponding to information at the first phase T_1. In this example, the voltage for writing "black" at phase T_1 is $3V_0$ and the application time is Δt. The voltage applied to the respective picture elements except at the scanning time is $|\pm V_0|$ to the maximum, and the longest time during which the maximum voltage is 2Δt as shown at part 40 in Figure 4B. The severest condition is imposed when the information signals succeed in the order of white → white → black and the second "white" signal is applied at the scanning time. Even then, the application time is 4Δt which is rather short and does not cause crosstalk at all, whereby a displayed information is retained semipermanently after the scanning of the whole picture is once completed. For this reason, a refreshing step as required in a display device using a TN liquid crystal having no bistability is not required at all.

The optimum length of the second phase T_2 depends on the magnitude of the voltage applied to the data line. When a voltage having a polarity opposite to that of the information signal is applied, it is preferred that the time length is shorter for a larger voltage and longer for a shorter voltage. When the time is longer, it follows that a longer time is required for scanning the whole picture. Therefore, T_2 is preferably set to satisfy $T_2 \leq T_1$.

Figures 5 and 6 show a driving mode according to the present invention. Figures 5B(a) and 5B(b) show voltages applied to picture elements corresponding to "black" and "white", respectively, on a selected scanning line. Figures 5B(c) and 5B(d) show voltages applied to picture elements on a non-selected scanning line and on a data line to which "black" or "white" information signals are applied. Figure 6 (combination of Figures 6A and 6B) illustrate these signals applied in time series.

It will be noted that in Figure 6B that the portion of the waveform corresponding to portion 41 in Figure 4B remains at voltage V_0 for a maximum time of $T_1 + T_2$, rather than $2(T_1+T_2)$ as in Figure 4B.

Figure 7 (combination of Figures 7A and 7B) illustrates another embodiment of the erasure step than the one explained with reference to Figure 4. Thus, in this example, the polarities of electric signals applied to scanning lines and data lines in the erasure step are made opposite to those of the scanning selection signals and information selection signals in the writing step. The voltage V_0 is also set to a value satisfying the relationships of $V_0 < V_{th1} < 3V_0$ and $-V_0 > -V_{th2} > -3V_0$.

In the embodiment shown in Figure 7, in the erasure step Δt, an electric signal of $2V_0$ is applied to the scanning lines at a time and, in phase with the electric signal, a signal of $-V_0$ with a polarity oppoiste to that of the electric signal is applied to the data lines. In the next writing step, signals similar to writing signals explained with reference to Figures 3 and 4 are applied to the scanning lines and data lines.

Figure 8 (combination of Figures 8A and 8B) and Figure 9 (combination of Figures 9A and 9B) respectively show examples of driving modes which are not embodiments of the present invention. In these driving modes, a voltage value V_0 is so set that the threshold voltage for changing orientations for a pulse width Δt is placed between $|V_0|$ and $2|V_0|$.

In Figure 8 (Figures 8A and 8B), an electric signal of $+V_0$ is applied to the scanning lines and, in phase therewith, an electric signal of $-V_0$ is applied to the data lines for erasing a picture. Immediately thereafter and subsequently, in the writing step, scanning signals of S_1, S_2, ..., each of $-V_0$, are sequentially applied and, in phase with these scanning signals, information signals, each of $+V_0$, are applied to data lines, whereby writing is carried out.

Figures 8 and 9 respectively show examples where no auxiliary signal is involved, whereas Figure 10 (combination of Figures 10A and 10B) shows an example where an auxiliary signal is used. Voltage values in respective driving pulses are shown in the figure. In the example of Figure 10, electric signals applied to scanning lines and data lines in the erasure step have polarities respectively opposite to those applied in the writing step, have magnitudes in terms of absolute values smaller (2/3 V_0) than those of the latter and have larger pulse widths ($2\Delta t$) than those of the latter. This erasure mode is effective in a case where the threshold voltage depends on pulse widths and a threshold voltage $V_{th}^{2\Delta t}$ for a width of $2\Delta t$ satisfies a relationship of $V_{th}^{2\Delta t} \leqq 4/3\ V_0$.

Figure 11 (inclusive of Figures 11A, 11B and 11C) and Figure 12 (combination of Figures 12A and 12B) illustrate a driving mode for an optical modulation device comprising:

a partial erasure step wherein electric signals are applied to selected scanning lines among the scanning lines and selected data lines; the selected scanning lines and selected data lines constituting a new image area where a new image is to be written, and the electric signals applied to the selected scanning lines and selected data lines having polarities opposite to those of a scanning selection signal and an information selection signal applied to the respective lines for writing images; whereby the optical modulation material constituting the new image area is oriented to the first stable state and an image written in a previous writing step is partially erased; and

a partial writing step wherein a scanning selection signal is applied to the selected scanning lines and an information signal for orienting the optical modulation material to the second stable step is applied to the selected data lines corresponding to information giving the new image.

A preferred embodiment of the above mentioned driving mode will be explained with reference to Figure 11.

Figure 11A schematically shows a cell 111 having picture elements arranged in a matrix which comprise scanning lines (scanning electrodes), data lines (signal electrodes) and a bistable optical modulation material interposed therebetween. Reference numeral 112 denotes data lines. For the brevity of explanation, a case where two state signals of "white" and "black" are displayed is explained. It is assumed that hatched picture elements correspond to "black" and the other picture elements correspond to "white" in Figure 3A. First, in order to make a picture uniformly "white" (this step is called an "erasure step"), the bistable optical modulation material may be uniformly oriented to the first stable state. This can be effected by applying a predetermined voltage pulse signal (e.g., voltage: $+2V_0$, time width : Δt) to all the scanning lines and applying a predetermined pulse signal (e.g., $-V_0$, Δt) to all the data lines. In the erasure step, an electric signal of a polarity opposite to that of a scanning selection signal in the writing step described hereinbelow is applied to the scanning lines, and an electric signal of a polarity opposite to that of an information selection signal (writing signal) in the writing step is applied to the data line, in phase with each other.

Figure 11B(a) and 11B(b) show an electric signal (scanning selection signal) applied to a selected scanning line and an electric signal (scanning non-selection signal) applied to the other scanning lines (nonselected scanning lines), respectively. Figures 11B(c) and 11B(d) show an electric signal (information selection signal; V_0 applied at phase T_1) applied to a selected (referred to as "black") data line and an electric signal (infor tion non-selection signal; $-V_0$ at phase T_1) applied to a non-selected (referred to as "white") data line, respectively. In the Figure 11B(a) - 11B(d), the abscissa represents time, and the ordinate a voltage, respectively. T_1 and T_2 in the figures represent a phase for applying an information signal (and scanning signal) and a phase for applying an auxiliary signal. This example shows a case where $T_1 = T_2 = \Delta t$.

The scanning lines 112 are selected sequentially. It is assumed herein that a threshold voltage for providing the first stable state (white) of the bistable liquid crystal at an application time of Δt be $-V_{th2}$, and a threshold voltage for providing the second stable state at an application time of Δt be V_{th1}. Then, the electric signal applied to the selected scanning line comprises voltages of $-2V_0$ at phase (time) T_1 and 0 at phase (time) T_2 as shown in Figure 11B(a). The other scanning lines are placed in grownded condition as shown in Figure 11B(b) and the electric signal is 0. On the other hand, the electric signal applied to the selected data line comprises V_0 at phase T_1 and $-V_0$ at phase T_2 as shown in Figure 11B(c), and the electric signal applied to the nonselected data line comprises $-V_0$ at phase T_1 and $+V_0$ at phase T_2 as shown in Figure 11B(d). In this instance, the voltage V_0 is set to a desired value which satisfies $V_0 < V_{th1} < 3V_0$ and $-V_0 > -V_{th2} > -3V_0$.

Voltage waveforms applied to respective picture elements when the above mentioned electric signals are given are shown in Figures 11C. Figures 11C(a) and 11C(b) show voltage waveforms applied to picture elements where "black" and "white" are displayed, respectively, on the selected scanning line. Figures 11C(c) and 11C(d) respectively show voltage waveforms applied to picture elements on the nonselected scanning lines.

At phase T_1, on the scanning line to which a scanning selection signal $-2V_0$ is applied, an information signal $+V_0$ is applied to a picture element where "black" is to be displayed and, therefore, a voltage $3V_0$ exceeding the threshold voltage V_{th1} is applied to the picture element, where the bistable liquid crystal is oriented to the second optically stable state. Thus, the picture element is written in "black" (writing step). On the same scanning line, the voltage applied to picture elements where "white" is to be displayed is a voltage V_0 which does not exceed the threshold voltage V_{th1}, and accordingly the picture element remains in the first optically stable state, thus displaying "white".

On the other hand, on the nonselected scanning lines, the voltage applied to all the picture elements is $\pm V$ or 0, each not exceeding the threshold voltage. Accordingly, the liquid crystal at the respective picture elements retains its orientation which has been obtained when the picture elements have been last scanned. In other words, after the whole picture elements have been oriented to one optically stable state ("white"), when one scanning line is selected, signals are written in one line of picture elements at the first phase T_1 and the written signal or display states are retained even after steps for writing one frame is finished.

Figure 11A shows an example of a picture thus formed through the erasure step and the writing step. Figure 11D shows an example of a picture obtained by partially rewriting the picture shown in Figure 11A. This example shown in Figure 11D illustrates a case where an X-Y region or area formed by scanning lines X and data lines Y is intended to be rewritten. For this purpose, an electric signal (e.g., $2V_0$ shown in Figure 12) having a polarity opposite to that of a scanning selection signal (e.g., $-2V_0$ in Figure 12) applied in the previous writing step is applied at a time or sequentially to scanning lines S_1, S_2 and S_3 corresponding to the new image region (X-Y region) to be rewritten. On the other hand, an electric signal (e.g., $-V_0$ on line I_1 in Figure 12) having a polarity opposite to that of an information selection signal (e.g., V_0 on I_1 in Figure 12) is applied to data lines I_1 and I_2 corresponding to the new image region. Thus, only a part (e.g., X-Y region) of one picture can be erased (Partial Erasure Step).

The writing in the partially erased region (X-Y region) is then effected by applying the same procedure as in the writing step, i.e., by applying an information selection signal ($+V_0$) and an information non-selection signal ($-V_0$) corresponding to predetermined rewriting image information to the data lines for the partially erased region in phase with a scanning selection signal ($-2V_0$).

On the other hand, an electric signal below the threshold voltage of the ferroelectric liquid crystal is applied to the picture elements in the non-rewriting region (i.e., X_a-Y, X_a-Y_a and X-Y_a regions) so that the writing state of each picture element in the non-rewriting region is retained.

More specifically, in the partial erasure step, an electric signal (e.g., V_0 on I_3 in Figure 12) having the same polarity as an electric signal (e.g., $2V_0$ in Figure 12) applied to the scanning signal in the erasure step is applied to the data lines not constituting the rewriting region (X-Y region). Further, in the partial writing step, an electric signal (e.g., $-V_0$ on I_3 in Figure 12) having the same polarity as a scanning selection signal (e.g., $-2V_0$ S_1, S_2 and S_3 in Figure 12) is applied to the data lines not constituting the rewriting region (X-Y region) in phase with the selection scanning signal. On the other hand, the potential of the scanning lines not constituting the rewriting region is held at a base potential (e.g., 0 volt).

The above explained driving signals are shown in time series in Figure 12 (combination of Figures 12A and 12B). S_1 - S_5 indicate electric signals applied to scanning signals; I_1 and I_3 indicate electric signals applied to data lines; and A_2, C_2 and D_2 indicate waveforms applied to picture elements A_2, C_2 and D_2 shown in Figures 11A and 11D.

A rewriting region can be appointed by a cursor in the present invention.

Figure 13 (combination of Figures 13A and 13B) and Figure 14 (combination of Figures 14A and 14B) show other examples of driving modes based on the present invention. In these driving modes, V_0 is set to such a value that the threshold voltage for changing orientations for a pulse width of Δt is placed between $|V_0|$ and $|2V_0|$.

In the example shown in Figure 13 (Figure 13A and Figure 13B), an electric signal of $+V_0$ is applied to the scanning lines and, in parallel therewith, an electric signal of $-V_0$ is applied to the data lines for erasing a picture. Immediately thereafter, in the writing step, scanning signals S_1, S_2 ...., each of $-V_0$, are sequentially applied and, in phase with these scanning signals, information signals, each of $+V_0$, are applied to data lines, whereby a picture as shown in Figure 11A is written in.

Next, in the partial erasure step, an electric signal of $-2V_0$ is applied to the picture elements which have been written in the previous step in the X-Y region shown in Figure 11D, whereby the picture elements are erased at a time. (This example of one time erasure is shown in Figure 13. However, successive erasure is also possible by applying an electric signal of V_0 successively to scanning lines as a scanning selection signal). Then, electric signals corresponding to new image information are applied to the X-Y region whereby the X-Y region is written as shown in Figure 11D.

Figures 13 and 14, not forming embodiments of the invention, respectively show examples where no auxiliary signal is involved, whereas Figure 15 (combination of Figures 15A and 15B) shows an example where an auxiliary signal is used. Voltage values in respective driving pulses are shown in the figure. In the example of Figure 15, electric signals applied to scanning lines and data lines in the erasure step have polarities respectively opposite to those applied in the writing step, have magnitudes in terms of absolute values smaller ($2/3\ V_0$) than those of the latter and have larger pulse widths ($2\Delta t$) than those of the latter. This erasure mode is effective in a case where the threshold voltage depends on pulse widths and a threshold voltage $V_{th}^{2\Delta t}$ for a width of $2\Delta t$ satisfies a relationship of $V_{th}^{2\Delta t} \leqq 4/3\ V_0$.

In the partial erasure step, an electric signal of $-4/3\ V_0$ is applied to effect partial erasure. In the next partial writing step, a new image is written in the X-Y region.

The driving method according to the present invention can be widely applied in the field of optical shutters and display such as liquid crystal-optical shutters and liquid crystal TV sets.

Hereinbelow, the present invention will be explained with reference to working examples.

Example 1

A pair of electrode plates each comprising a glass substrate and a transparent electrode pattern of ITO (Indium-Tin-Oxide) formed thereon were provided. These electrodes were capable of giving a 500 x 500 matrix electrode structure. On the electrode pattern of one of the electrode plates was formed a polyimide film of about 300Å in thickness by spin coating. The polyimide face of the electrode plate was rubbed with a roller about which a suede cloth was wound. The electrode plate was bonded to the other electrode plate which was not coated with a polyimide film, thereby to form a cell having a gap of about 1.6μ. Into the cell was injected a ferroelectric crystal of decyloxybenzylidene-p'-amino-2-methylbutyl cinnamate (DOBAMBC) under hot-melting state, which was then gradually cooled to form a uniform monodomain of SmC phase .

The thus formed cell was held at a controlled temperature of 70°C and driven by line-by-line scanning according to the driving mode explained with reference to Figure 7 under the conditions of V_0 = 10 volt, and $T_1 = T_2 = \Delta t$ = 80 μsec, whereby a good image was obtained.

Example 2

Line-by-line scanning was carried out in the same manner as in Example 1 except that the driving waveforms shown in Figure 12 was used, whereby extremely good image was formed. Then, a part of the image was rewritten according to driving waveforms shown in Figure 12, whereby good partially-rewritten image was obtained.

Reference is directed to United Kingdom Patent Applicaton No GB 2204172 A (8726218) which is divided from this application.

CLAIMS

1. A driving method for an optical modulation device having a plurality of electro-optical elements arranged in a matrix and comprising scanning lines, data lines spaced apart from and intersecting with the scanning lines, and a ferroelectric liquid crystal which assumes a first orientation state or a second orientation state depending on the direction of an electric field applied thereto interposed between the scanning lines and data lines, each of the intersections between the scanning lines and the data lines forming one of said electro-optical elements; said driving method comprising:

an erasure step wherein a voltage exceeding a first threshold voltage of the ferroelectric liquid crystal for causing the first orientation state of the ferroelectric liquid crystal is applied to the intersections of the scanning lines and the data lines;

a writing step wherein a scanning selection signal comprising a voltage of one polarity and a voltage of the other polarity with respect to the voltage of a non-selected scanning line is applied to a selected scanning line, an information selection signal providing a voltage exceeding a second threshold voltage of the ferroelectric liquid crystal for causing the second orientation state of the ferroelectric liquid crystal in combination with the voltage of one polarity of the scanning selection signal is applied to a selected data line, an information non-selection signal providing a voltage between the first and second threshold voltages of th ferroelectric liquid crystal in combination with the voltage of one polarity of the scanning selection signal is applied to other data lines, and an auxiliary signal for preventing unintentional inversion of the orientation states of the ferroelectric liquid crystal in combination with the voltage of the other polarity of the scanning selection signal is applied to the data lines.

2. The method according to claim 1, wherein said information selection signal and information non-selection signal have different voltage polarities with respect to the voltage of the non-selected scanning line.

3. The method according to claim 1 or 2, wherein the auxiliary signal applied to the selected data line in phase with said voltage of the other polarity of the scanning selection signal has a voltage polarity

opposite to that of the information selection signal immediately before or after the auxiliary signal, with respect to the voltage of the non-selected scanning lines.

4. The method according to any preceding claim, wherein in said erasure step, the voltage exceeding the first threshold voltage of the ferroelectric liquid crystal is applied to all or a part of said plurality of electro-optical elements.

5. The method according to claim 4, wherein said voltage applied to the electro-optical elements in the erasure step comprises a combination of voltage signals applied to the associated scanning line and data line having voltage polarities opposite to each other with respect to the voltage of the scanning line to which the scanning selection signal is not applied in the writing step.

6. The method according to claim 4 or 5, wherein said erasure step is applied to a part of said plurality of said electro-optical elements, and a non-erasing data voltage signal is applied to the data lines connected to the remaining electro-optical elements other than said part of the electro-optical

elements in the erasure step, said non-erasing data voltage signal having a polarity similar to that of the voltage signal applied to the scanning line in the erasure step with respect to the voltage of the non-selected scanning line.

7. The driving method according to claim 4, wherein said erasure step is applied to a part of said plurality of said electro-optical elements, and a non-erasing data voltage signal is applied to the data lines connected to the remaining electro-optical elements other than said part of the electro-optical elements in the erasure step, said non-erasing data voltage signal having voltage equal to that of the scanning selection signal.

8. The method according to any preceding claim, wherein said information selection signal has a pulse width which is greater than the pulse width of said auxiliary signal.

9. The method according to any preceding claim, which comprises applying an alternating voltage below the threshold voltages to the electro-optical elements on the non-selected scanning line.

10. An optical modulation device having a plurality of electro-optical elements arranged in a matrix and comprising scanning lines, data lines spaced apart from and intersecting with the scanning lines and a ferroelectric liquid crystal which assumes a first orientation state or a second orientation state depending on the direction of an electric field applied thereto interposed between the scanning lines and the data lines, each of the intersections between the scanning lines and the data lines forming one of said electro-optical elements; said optical modulation device comprising:

an erasure means by which a voltage exceeding a first threshold voltage of the ferroelectric liquid crystal for causing the first orientation state of the ferroelectric liquid crystal is applied to the intersections of the scanning lines and the data lines;

a writing means by which a scanning selection signal comprising a voltage of one polarity and a voltage of the other polarity with respect to the voltage of a non-selected scanning line is applied to a selected scanning line, an information selection signal providing a voltage exceeding a second threshold voltage of the ferroelectric liquid crystal for causing the second orientation state of the ferroelectric liquid crystal in combination with the voltage of one polarity of the scanning selection signal is applied to a selected data line, an information non-selection signal providing a voltage between the first and second threshold voltages of the ferroelectric liquid crystal in combination with the voltage of one polarity of the scanning selection signal is applied to other data lines, and an auxiliary signal for preventing unintentional inversion of the orientation states of the ferroelectric liquid crystal in combination with the voltage of the other polarity of the scanning selection signal is applied to the data lines.

11. A device according to claim 10, and including means for applying an alternating voltage below the threshold voltages to the electro-optical elements on the non-selected scanning line.

12. A driving method for an optical modulation device having a plurality of electro-optical elements arranged in a matrix and comprising scanning lines, data lines spaced apart from and intersecting with the scanning lines, and a ferroelectric liquid crystal which assumes a first orientation state or a second orientation state depending on the direction of an

electric field applied thereto interposed between the scanning lines and the data lines, each of the intersections between the scanning lines and the data lines forming one of said electro-optical elements; said driving method comprising:

a step of forming an image area comprising electro-optical elements wherein the ferroelectric liquid crystal assumes the first orientation state formed by application of a voltage of one polarity exceeding a first threshold voltage of the ferroelectric liquid crystal and electro-optical elements wherein the ferroelectric liquid crystal assumes the second orientation state formed by application of a voltage of the other polarity exceeding a second threshold voltage of the ferroelectric liquid crystal, a rewriting region being defined in the image area;

a first step wherein, in the rewriting region, a voltage of one polarity exceeding the first threshold voltage of the ferroelectric liquid crystal is applied to the intersections of a scanning line and the data lines; and

a second step wherein a scanning selection signal is applied to a scanning line in the rewriting region, an information selection signal providing a voltage of the other polarity exceeding the second threshold voltage of the ferroelectric liquid crystal in combination with the scanning selection signal and an auxiliary signal are applied to a selected data line in the rewriting region, and a voltage of the same voltage level as a scanning non-selection signal applied to a non-selected scanning line in the rewriting region is applied to scanning lines outside the rewriting region;

the auxiliary signal providing an inversion preventing voltage in combination with the scanning non-selection signal applied to a non-selected scanning line before the application period of a voltage of a particular polarity reaches a period beyond which the first or second orientation state of an electro-optical element on the non-selected scanning line is unintentionally inverted due to said voltage of said particular polarity and less than the relevant threshold voltage, the inversion preventing voltage being a zero voltage or having a polarity opposite to said particular polarity.

13. The method according to claim 12, wherein, in the first step, a voltage signal, having the same polarity as that of a voltage signal applied to the scanning line and providing said voltage of one polarity in said first step, is applied to the data lines

connected to the electro-optical elements other than said rewriting region.

14. The method according to claim 12, wherein, in the second step, a voltage signal, having the same polarity as that of the scanning selection signal in said second step, is applied to the data lines other than those connected to the electro-optical elements of said rewriting region.

15. The method according to any of claims 12 to 14, wherein said step of forming an image area comprises:

an erasure step wherein a voltage signal of one polarity, with respect to the voltage level of a non-selected scanning line in a writing step, is applied to a plurality of scanning lines, and a voltage signal providing a voltage exceeding the first threshold voltage of the ferroelectric liquid crystal for causing the first orientation state of the ferroelectric liquid crystal in combination with said voltage signal of one polarity is applied to a plurality of data lines;

the writing step wherein a scanning selection signal is applied to a selected scanning line, the scanning selection signal comprising a voltage signal of the other polarity with respect to the voltage level of the non-selected scanning line; a voltage signal providing a voltage exceeding the second threshold voltage of the ferroelectric liquid crystal for causing the second orientation state of the ferroelectric liquid crystal in combination with said voltage signal of the other polarity is applied to a selected data line; and a voltage signal providing a voltage between the first and second threshold voltages of the ferroelectric liquid crystal in combination with said voltage signal of the other polarity.

16. The method according to claim 15, wherein in said writing step, the voltage signals, applied to said selected data line and said the other data line in phase with said voltage signal of the other polarity of the scanning selection signal, having mutually opposite polarities with respect to the voltage level of the non-selected scanning line.

17. The method according to claim 15 or 16, wherein said erasure step is a step wherein an image written in the matrix of electro-optical elements is erased at one time.

18. The method according to any of claims 12 to 17, wherein said first step is a step wherein the rewriting region is erased at one time.

19. The method according to any of claims 12 to 17, wherein said first step is a step wherein the rewriting region is erased line by line with respect to the scanning lines.

20. The method according to any of claims 12 to 19, wherein, in the second step, the scanning lines other than those constituting the rewriting region are held at the same voltage level as the non-selected scanning line.

21. An optical modulation device having a plurality of electro-optical elements arranged in a matrix and comprising scanning lines, data lines spaced apart from and intersecting with the scanning lines, and a ferroelectric liquid crystal which assumes a first orientation state or a second orientation state depending on the direction of an electric field applied thereto interposed between the scanning lines and the data lines, each of the intersections between the scanning lines and the data lines forming one of said electro-optical elements; said optical modulation

device comprising means for effecting:

a step of forming an image area comprising electro-optical elements wherein the ferroelectric liquid crystal assumes the first orientation state formed by application of a voltage of one polarity exceeding a first threshold voltage of the ferroelectric liquid crystal and electro-optical elements wherein the ferroelectric liquid crystal assumes the second orientation state formed by application of a voltage of the other polarity exceeding a second threshold voltage of the ferroelectric liquid crystal, a rewriting region being defined in the image area;

a first step wherein, in the rewriting region, a voltage of one polarity exceeding the first threshold voltage of the ferroelectric liquid crystal is applied to the intersections of a scanning line and the data lines; and

a second step wherein a scanning selection signal is applied to a scanning line in the rewriting region, an information selection signal providing a voltage of the other polarity exceeding the second threshold voltage of the ferroelectric liquid crystal in combination with the scanning selection signal and an auxiliary signal are applied to a selected data line in the rewriting region, and a voltage of the same voltage level as a scanning non-selection signal applied to a non-selected scanning line in the rewriting region is applied to scanning lines outside the rewriting region;

the auxiliary signal providing an inversion preventing voltage in combination with the scanning non-selection signal applied to a non-selected scanning line before the application period of a voltage of a particular polarity reaches a period beyond which the first or second orientation state of an electro-optical element on the non-selected scanning line is unintentionally inverted due to said voltage of said particular polarity and less than the relevant threshold voltage, the inversion preventing voltage being a zero voltage or having a polarity opposite to said particular polarity.

22. A driving method for an optical modulation device having a plurality of electro-optical elements arranged in the form of a matrix and comprising scanning lines, data lines spaced apart from and intersecting with the scanning lines, and a ferroelectric liquid crystal interposed between the scanning lines and the data lines, each of the intersections between the scanning lines and the data lines forming one of said electro-optical elements;

said driving method comprising:

a first step wherein a voltage exceeding a first threshold voltage of the ferroelectric liquid crystal for providing a first orientation state of the ferroelectric liquid crystal is applied to the intersections of the scanning lines and the data lines; and

a second step wherein a scanning selection signal is applied to a scanning line, and information selection signal providing a voltage exeeding a second threshold voltage of the ferroelectric liquid crystal for providing a second orientation state of the ferroelectric liquid crystal in combination with the scanning selection signal and an auxiliary signal are applied to a selected data line in the same time period as the scanning selection signal;

said auxiliary signal providing an inversion preventing voltage in combination with a voltage applied to a non-selected scanning line before the application period of a voltage of a particular polarity reaches a period beyond which the first or second orientation state of an electro-optical element on the non-selected scanning line is unintentionally inverted due to said voltage of said particular polarity and less than the relevant threshold voltage, the inversion preventing voltage having a polarity opposite to said particular polarity;

the voltage signals applied to the scanning lines and the data lines in the first step having polarities opposite to those of the scanning selection signal and the information selection signal, respectively, applied in the second step with respect to the voltage applied to the non-selected scanning line;

the voltage signals applied to the scanning lines and the data lines in the first step having mutually opposite polarities with respect to the voltage applied to the non-selected scanning line.

23. An optical modulation device having a plurality of electro-optical elements arranged in the form of a matrix and comprising scanning lines, data lines spaced apart from and intersecting with the scanning lines, and a ferroelectric liquid crystal interposed between the scanning lines and the data lines, each of the intersections between the scanning lines and the data lines forming one of said electro-optical elements; said optical modulation device comprising means for effecting:

a first step wherein a voltage exceeding a first threshold voltage of the ferroelectric liquid crystal for providing a first orientation state of the ferroelectric liquid crystal is applied to the intersections of the scanning lines and the data lines; and

a second step wherein a scanning selection signal is applied to a scanning line, and information selection signal providing a voltage exceeding a second threshold voltage of the ferroelectric liquid crystal for providing a second orientation state of the ferroelectric liquid crystal in combination with the scanning selection signal and an auxiliary signal are applied to a selected data line in the same time period as the scanning selection signal;

said auxiliary signal providing an inversion preventing voltage in combination with a voltage applied to a non-selected scanning line before the application period of a voltage of a particular polarity reaches a period beyond which the first or second orientation state of an electro-optical element on the non-selected scanning line is unintentionally inverted due to said voltage of said particular polarity and less than the relevant threshold voltage, the inversion preventing voltage having a polarity opposite to said particular polarity;

the voltage signals applied to the scanning lines and the data lines in the first step having polarities opposite to those of the scanning selection signal and the information selection signal, respectively, applied in the second step with respect to the voltage applied to the non-selected scanning line;

the voltage signals applied to the scanning lines and the data lines in the first step having mutually opposite polarities with respect to the voltage applied to the non-selected scanning line.

24. A method or device as claimed in any preceding claim wherein said ferroelectric liquid crystal is a chiral smectic liquid crystal.

25. A method or device according to claim 24, wherein said chiral smectic liquid crystal is in a nonspiral structure.

26. A method or device as claimed in claim 24, wherein the liquid crystal is disposed in a layer thin enough to release the helical structure thereof.

27. A method or device as claimed in any of claims 24 to 26, wherein said chiral smectic liquid crystal is in C phase, H phase, I phase, J phase, K phase, G phase or F phase.

28. A ferroelectric liquid crystal device of the type

on which the method of any of claims 1 to 9, 12 to 20, 22 and 24 to 27 can be performed and having a drive circuit for performing the method of that claim.

29. An optical modulation device or driving method therefor substantially as described in the description with reference to Figures 1 and 2 in combination with Figures 5 and 6, or 7 or 10, or 11, 12 or 15 of the drawings.

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