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(54) **LIQUID CRYSTAL DISPLAY DEVICE,
POWER SUPPLY CIRCUIT, AND METHOD
FOR CONTROLLING LIQUID CRYSTAL
DISPLAY DEVICE**

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(57) **ABSTRACT**

(51) **Int. Cl.**
G09G 3/36 (2006.01)

A liquid crystal display device according to the present invention includes: a liquid crystal panel **11**; a source driver **12** for controlling the gray-scale level by applying a voltage to the liquid crystal panel **11**; a DC-DC power supply **13** for driving the source driver **12** by supplying current to the source driver **12**; a controller **14** for supplying a signal for controlling the gray-scale level to the source driver **12**; and a variation calculator **15** for calculating the amount of change in the signal from the controller **14**. In the DC-DC power supply **13**, current to be supplied to the source driver **12** changes in accordance with the amount of change in the signal calculated by the variation calculator **15**.

(52) **U.S. Cl.** **345/204**; 345/87; 345/90;
345/208; 345/211; 345/212; 348/655

(58) **Field of Classification Search** 345/87,
345/90, 204, 208, 211, 212; 348/655
See application file for complete search history.

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16 Claims, 8 Drawing Sheets

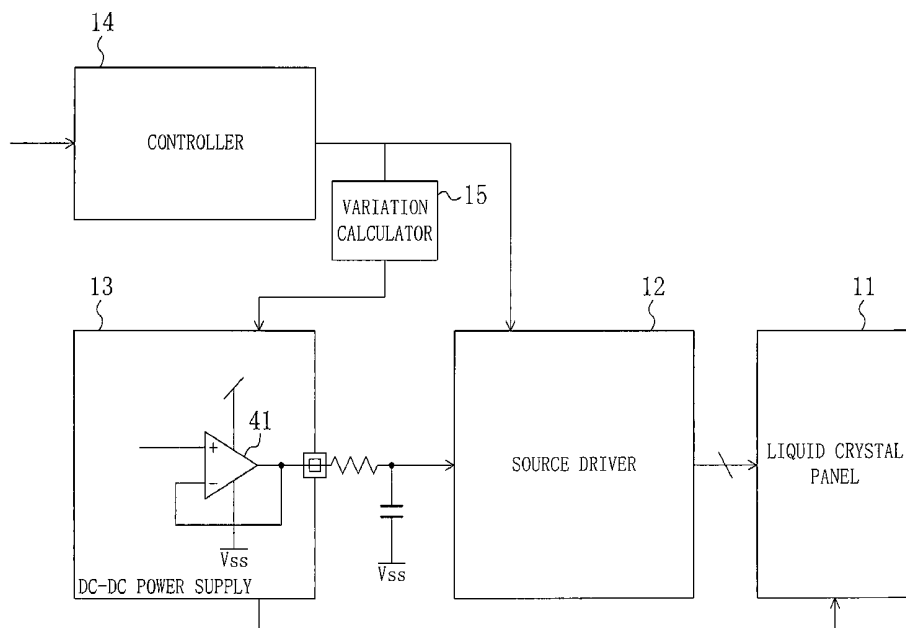


FIG. 1

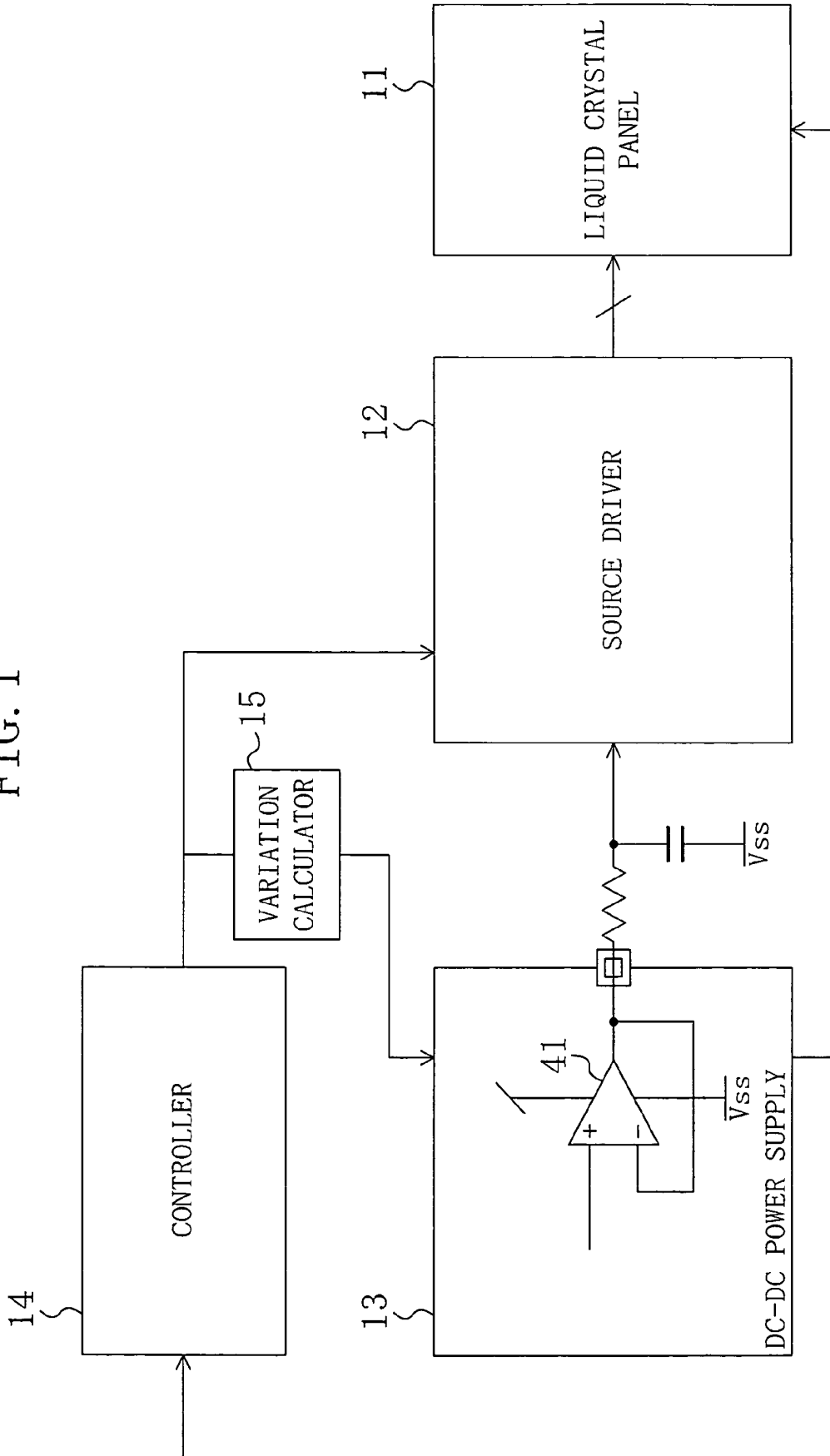


FIG. 2

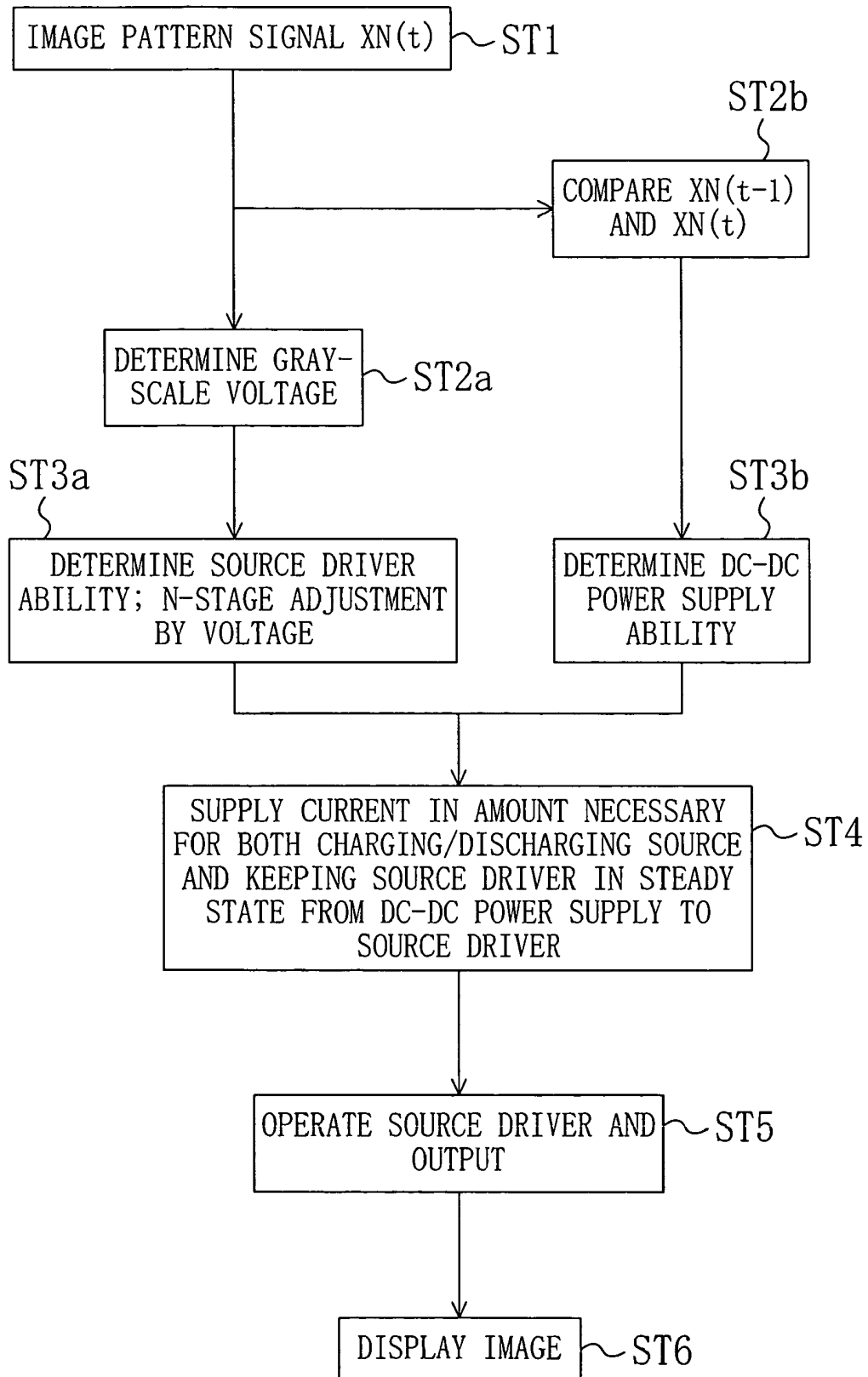
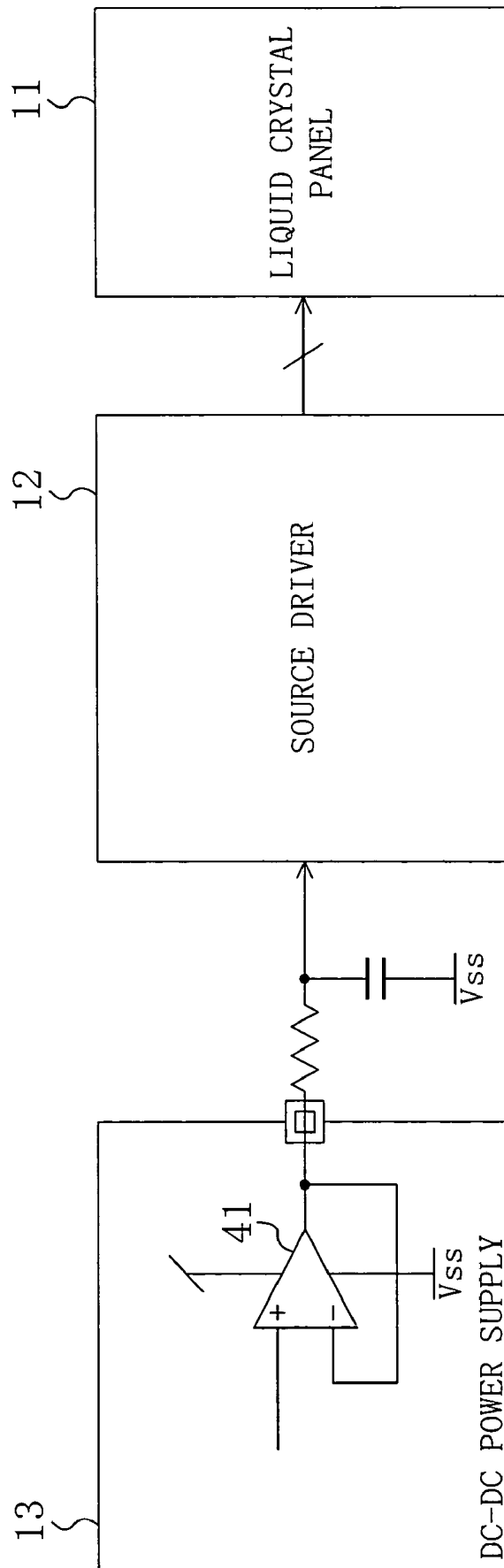


FIG. 3



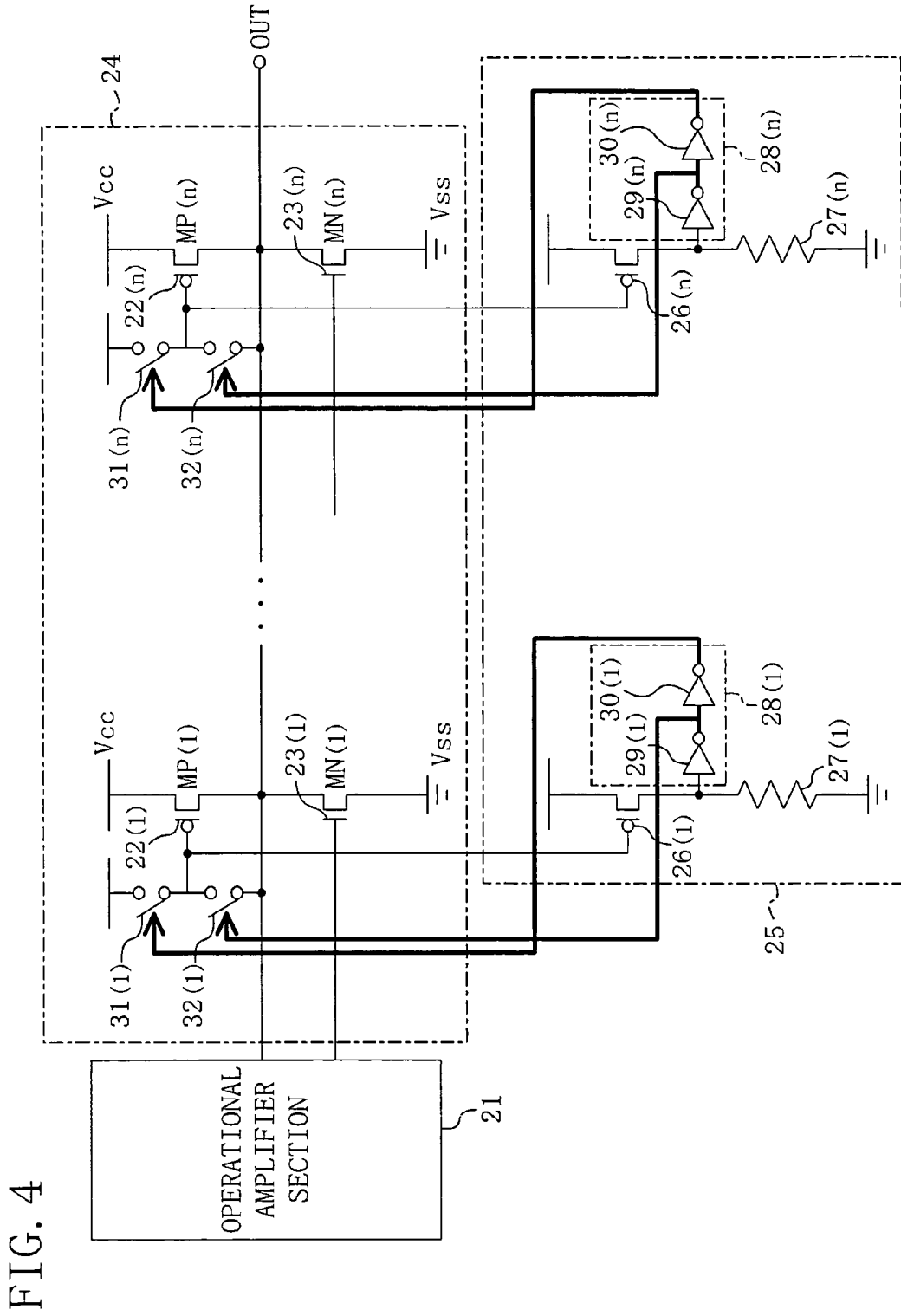


FIG. 5

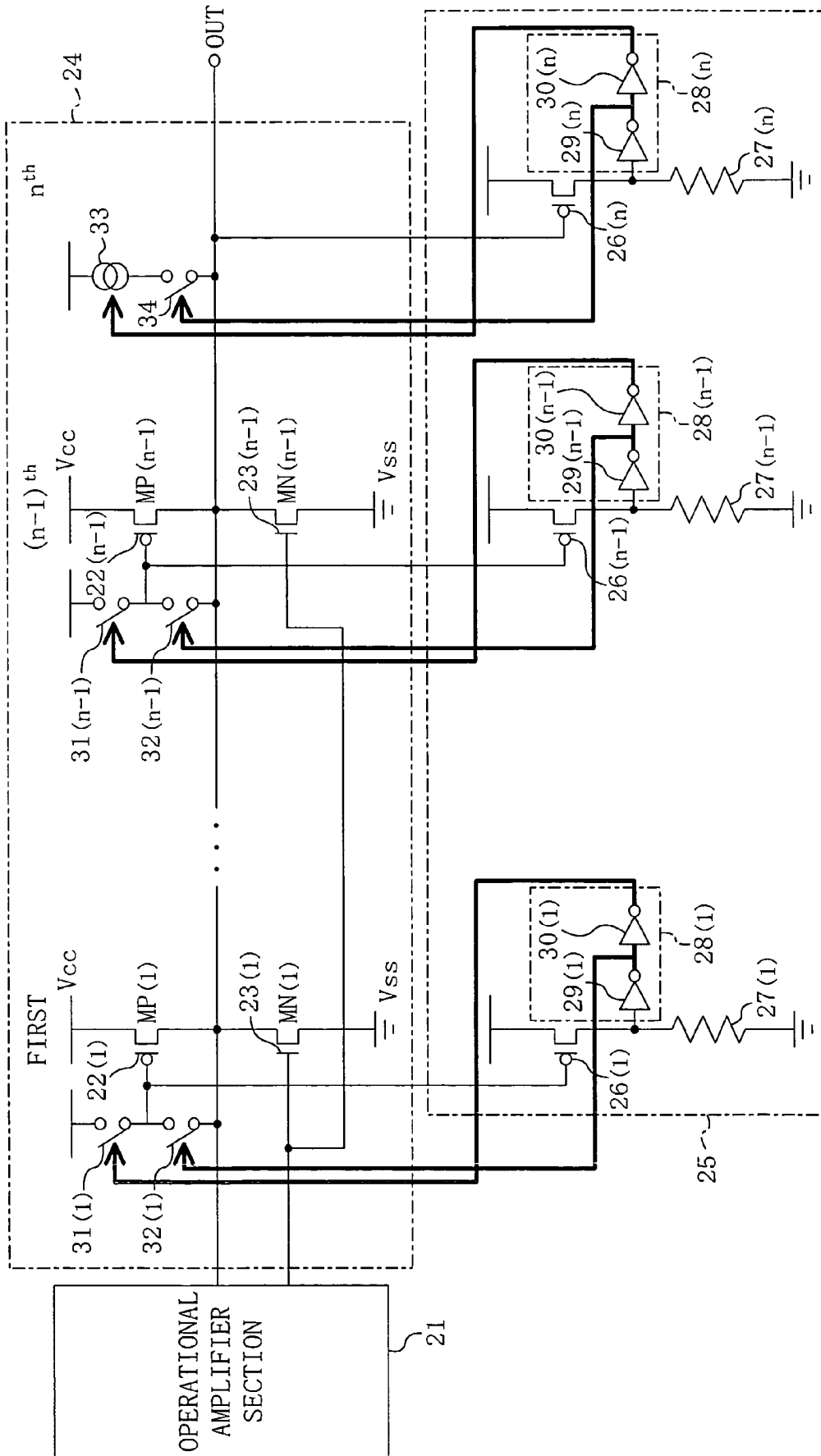


FIG. 6A

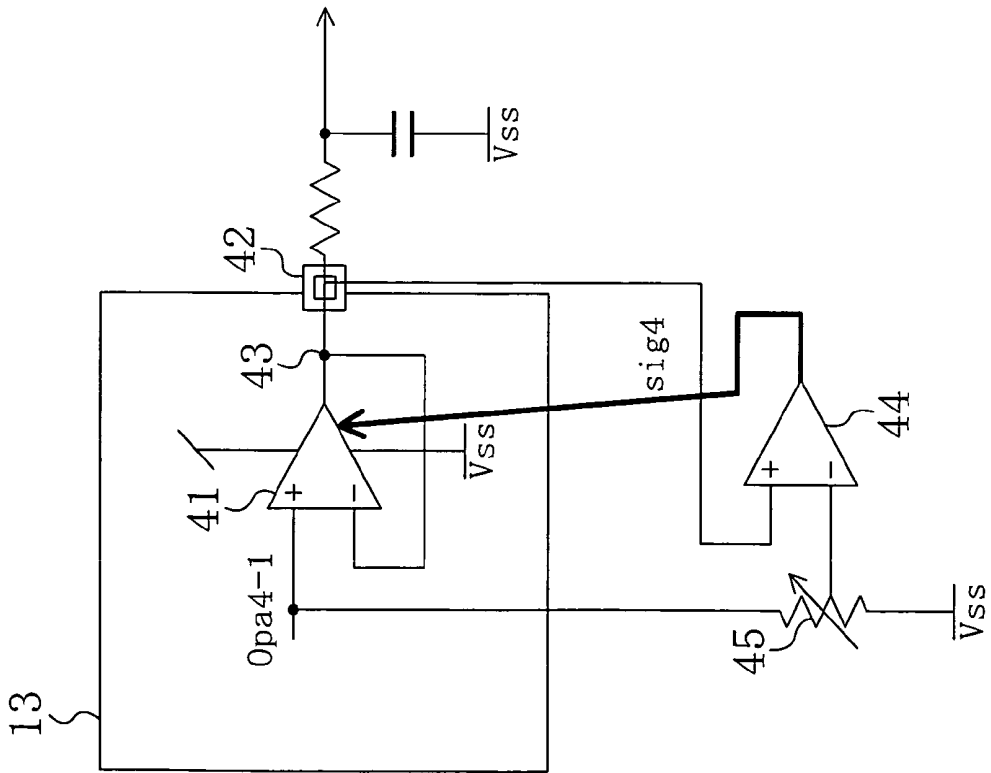
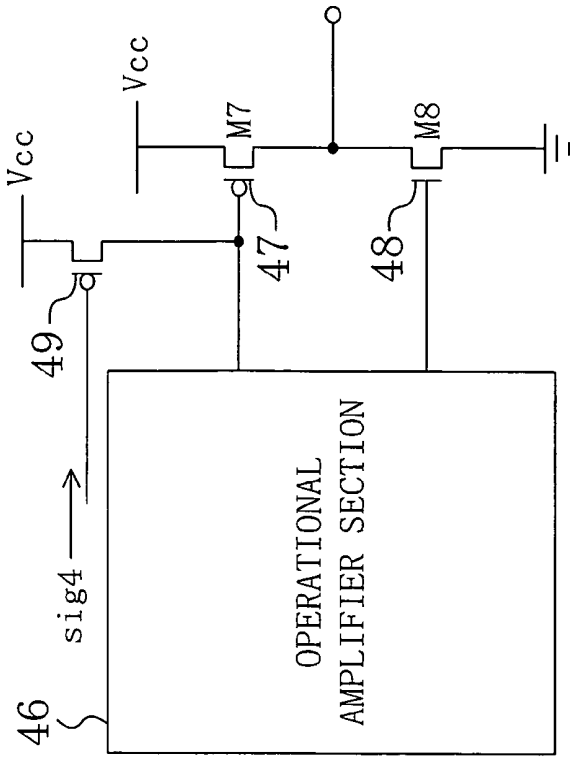


FIG. 6B



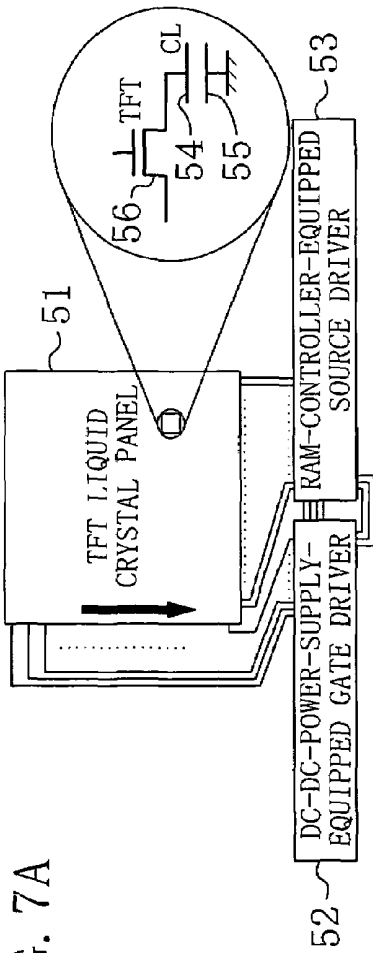


FIG. 7A

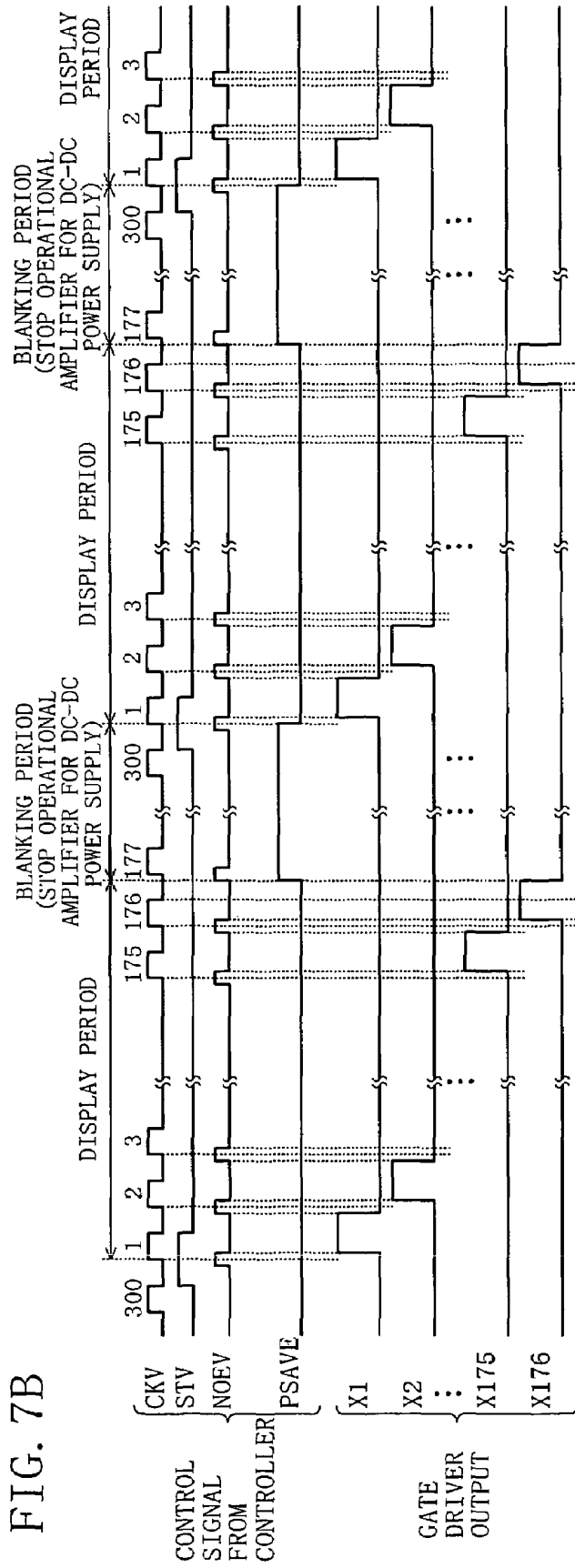
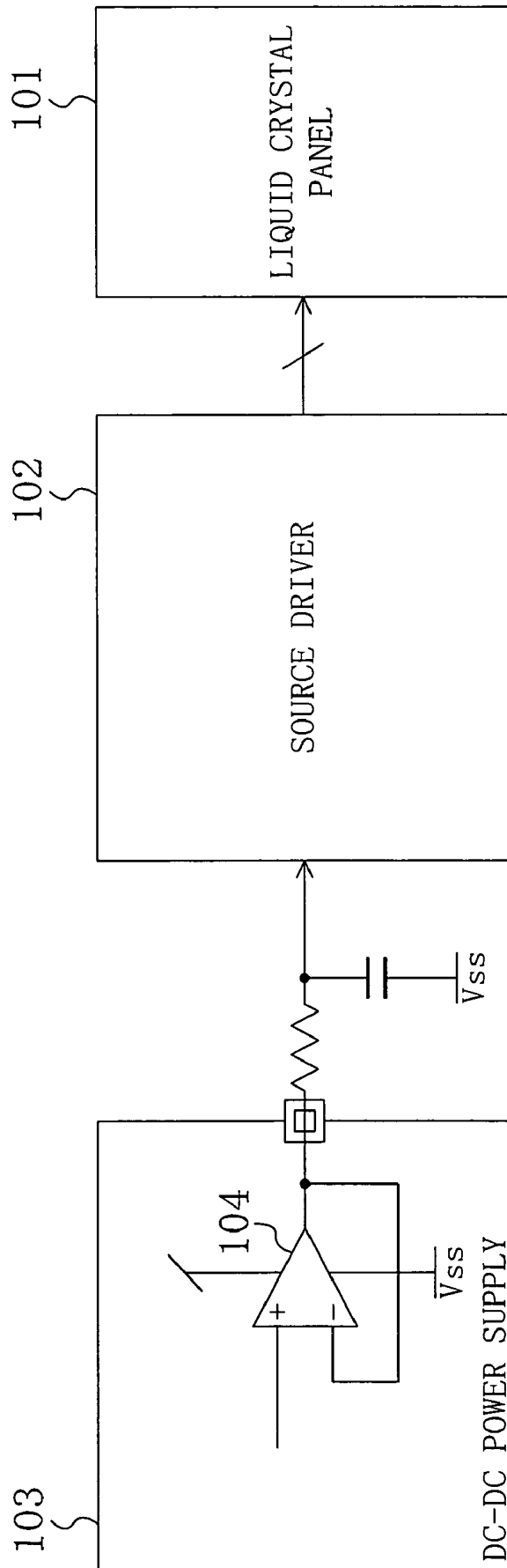


FIG. 7B

FIG. 8



**LIQUID CRYSTAL DISPLAY DEVICE,
POWER SUPPLY CIRCUIT, AND METHOD
FOR CONTROLLING LIQUID CRYSTAL
DISPLAY DEVICE**

The disclosure of Japanese Patent Application No. 2003-347878 filed Oct. 7, 2003 including specification, drawings and claims is incorporated herein by reference in its entirety.

BACKGROUND OF THE INVENTION

The present invention relates to liquid crystal display devices, power supply circuits for use in liquid crystal display devices or other devices, and methods for controlling liquid crystal display devices. In particular, the present invention relates to active-matrix-type liquid crystal display devices.

In recent years, liquid crystal display devices have been widely used as screens of TVs and personal computers, panels of mobile equipment, and others.

FIG. 8 is a diagram schematically showing a configuration of a conventional liquid crystal display device. Hereinafter, an active-matrix-type liquid crystal display device will be described.

As shown in FIG. 8, the conventional liquid crystal display device includes: a liquid crystal panel **101** including pixels (not shown) arranged in a matrix pattern; a source driver **102** for controlling the gray-scale levels of the pixels in the liquid crystal panel **101**; and a DC-DC power supply **103** for driving the source driver **102** by supplying current to the source driver **102**. Although not shown, a gate driver for switching the pixels in the liquid crystal panel **101**, a controller for supplying a control signal to the source driver **102** and other components are also provided.

In the liquid crystal panel **101**, liquid crystal is sandwiched between two opposed electrodes. One of the electrodes is connected to a thin film transistor (TFT) for each of the pixels. The gate of the TFT receives a voltage from the gate driver. Control of the voltage applied to the gate allows switching operation to be performed on each of the pixels. The source of the TFT receives a voltage from the source driver **102**. Control of the voltage applied to the source allows the gray-scale levels of the pixels to differ from one pixel to another. The source driver **102** receives a signal from the controller and a current from the DC-DC power supply **103**. A voltage from the DC-DC power supply **103** may be applied to the drain of the TFT (i.e., common electrode).

In the DC-DC power supply **103**, an operational amplifier **104** for amplifying an input voltage is provided. The operational amplifier **104** may be connected to a booster (not shown). The booster is used to boost a reference voltage supplied from an external power supply and to supply the boosted voltage to the operational amplifier **104**.

However, the conventional liquid crystal display device has the following drawback.

The DC-DC power supply **103** supplies a constant current I_{max} to the source driver **102**. The amount of this current I_{max} is sufficient for allowing the source driver **102** to operate at the maximum output. It was believed that the supply of such a sufficient amount of current allows the liquid crystal panel **101** to display a stable image. However, in fact, a large amount of current is constantly generated irrespective of display patterns on the liquid crystal panel **101**, resulting in high power consumption in the DC-DC power supply **103** and the source driver **102**.

Such a drawback is common to power supplies for supplying voltages to electrodes in the liquid crystal panel **101**.

SUMMARY OF THE INVENTION

It is therefore an object of the present invention to provide a liquid crystal display device exhibiting low power consumption without a loss of stability in image display by taking a means which allow the output of a power supply such as a DC-DC power supply to vary in accordance with the amount of change in display on a liquid crystal panel.

In order to achieve this object, a first inventive liquid crystal display device includes: a display section for displaying an image; a driver circuit for supplying an output signal for driving the display section; a controller circuit for supplying, to the driver circuit, a signal for controlling the output signal; a variation calculator for calculating the amount of change in the signal; and a power supply circuit for supplying, to the driver circuit, power with a value based on the amount of change in the signal.

In this device, power supplied from the power supply circuit varies depending on changes of the image on the display section. Accordingly, as compared to a conventional device in which power with a constant value is always supplied, power consumption is reduced without a loss of image quality on the display section.

The power supply circuit may adjust the amount of a current supplied to the driver circuit, in accordance with the amount of change in the signal.

A plurality of pixels may be provided in the display section, the driver circuit may apply, to the pixels, a voltage depending on the output signal, the variation calculator may calculate the amount of change in the signal for each of the pixels, and the power supply circuit may supply, to the driver circuit, a current in an amount proportional to the amount of change in the signal. In such a case, the time required for changing an image is uniform among the pixels, thus producing further stabilized displays.

A first inventive power supply circuit includes: an operational amplifier; an output transistor section including output transistors in a plurality of stages connected to an output of the operational amplifier; an I-V converter circuit including a transistor forming a current mirror together with an associated one of the output transistors; and a switching circuit for controlling an ON/OFF state of an associated one of the output transistors based on an output signal from the I-V converter circuit, the switching circuit being connected to the I-V converter circuit and the output transistor section.

In this device, the same amount of currents flow in both an output transistor and a transistor in the I-V converter circuit at an identical stage. The switching circuit controls the ON/OFF state of the output transistor in accordance with this amount, thus driving output transistors in the number associated with the number of stages necessary for allowing the current at this time to flow. That is, the number of stages of operating output transistors is adjusted at every change in display, so that power consumption is reduced without a loss of image quality.

The I-V converter circuit may further include: a resistor connected to the transistor in the I-V converter and a ground line; and an inverter section including a plurality of inverters, the inverter section having an input connected between the transistor in the I-V converter and the resistor and an output connected to the switching circuit. Then, desirable operation is achieved.

The output transistor section may include, as the output transistors: p-MIS transistors in the plurality of stages, each of the p-MIS transistors having a gate connected to the output of the operational amplifier and a source connected to a power line; and n-MIS transistors in the plurality of stages, each of

the n-MIS transistors having a gate connected to the output of the operational amplifier, a drain connected to a drain of an associated one of the p-MIS transistors, and a source connected to a ground line, and the transistor in the I-V converter circuit may be a p-MIS transistor of the same size as that of an associated one of the p-MIS transistors in the output transistor section.

Alternatively, the output transistor section may include, as the output transistors: pnp bipolar transistors in the plurality of stages, each of the pnp bipolar transistors having a base connected to the output of the operational amplifier and an emitter connected to a power line; and npn bipolar transistors in the plurality of stages, each of the npn bipolar transistors having a base connected to the output of the operational amplifier, a collector connected to a collector of an associated one of the pnp bipolar transistors, and an emitter connected to a ground line, and the transistor in the I-V converter circuit may be a pnp bipolar transistor having an emitter of the same size as that of an associated one of the pnp bipolar transistors, which is at the same stage, in the output transistor section.

This power supply circuit is preferably a power supply of a liquid crystal display device.

A current source may be connected to the output transistor section. Then, current can be generated before a capacitance depending on output transistors is completely charged. Accordingly, high-speed operation is achieved.

A second inventive liquid crystal display device includes: a display section for displaying an image; a power supply circuit for supplying power for controlling the image on the display section, the power supply circuit including an operational amplifier; a comparator for comparing an output from the operational amplifier with a standard value; and a switching section for controlling an ON/OFF state of the operational amplifier based on an output signal from the comparator.

In this device, if the output from the operational amplifier is sufficiently high, the operational amplifier is temporarily stopped and is not started again until the output becomes low. As a result, power consumption is reduced without a loss of image quality on the display section.

The operational amplifier may include a (+)-side input, a (-)-side input and an output, the comparator may include a (+)-side input, a (-)-side input and an output, the (+)-side input of the comparator may be connected to the output of the operational amplifier, the (-)-side input of the comparator may be connected to the (+)-side input of the operational amplifier, the output of the comparator may be connected to the switching section; and a resistor may be interposed between the (-)-side input of the comparator and the (+)-side input of the operational amplifier.

A third inventive liquid crystal display device includes: a display section for displaying an image; and a power supply circuit including an operational amplifier for supplying power for controlling the image on the display section, wherein the operational amplifier is stopped during a blanking period.

In this device, the operational amplifier is stopped only during the blanking period during which no write operation is performed on the display section whereas the operational amplifier is driven during an effective write period during which write operation is performed on the display section. As a result, power consumption is reduced without a loss of image quality on the display section.

The third liquid crystal display device may further include a controller circuit for generating a signal for controlling the image on the display section, wherein the operational amplifier is stopped during the blanking period based on the signal from the controller circuit.

It is preferable that the power supply circuit further includes a booster for boosting a voltage to be supplied to the operational amplifier, a clock signal is supplied from the controller circuit to the booster, and the frequency of the clock signal in the blanking period is lower than that in an effective write period. Then, power consumption is further reduced.

It is preferable that the display section includes an upper electrode, a lower electrode opposed to the upper electrode, a source line connected to the upper electrode, a gate line connected to both the source line and the gate line, and the liquid crystal display device further includes: a source driver for driving the source line, the source driver being connected to the transistor; and a gate driver for driving the gate line, the gate driver being connected to the transistor.

In this case, the power supply circuit may supply the power to either the source driver or the gate driver.

Alternatively, the power supply circuit may supply the power to the lower electrode.

An inventive method for controlling a liquid crystal display device including a display section, a driver circuit for supplying a voltage to the display section, a controller circuit for supplying, to the driver circuit, a signal for controlling the voltage, and a power supply circuit for supplying power to the driver circuit, includes: a first step of calculating the amount of change in the signal from the controller circuit; and a second step of supplying power from the power supply circuit to the driver circuit based on the amount of change in the signal.

With this method, power supplied from the power supply circuit varies depending on changes of the image on the display section. Accordingly, as compared to a conventional method in which constant power is always supplied, power consumption is reduced without a loss of image quality on the display section.

In the second step, the amount of a current supplied to the driver circuit may be adjusted in accordance with the amount of change in the signal.

A plurality of pixels may be provided in the display section, in the first step, the amount of change in the signal may be calculated for each of the pixels, and in the second step, a current in an amount proportional to the amount of change in the signal may be supplied to the driver circuit. In such a case, the time required for changing the image is uniform among the pixels, thus obtaining further stabilized displays.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a diagram schematically showing a configuration of a liquid crystal driver according to a first embodiment.

FIG. 2 is a flowchart showing steps of displaying an image on a liquid crystal panel based on a display pattern according to the first embodiment.

FIG. 3 is a diagram schematically showing a configuration of a liquid crystal driver according to a second embodiment.

FIG. 4 is a circuit diagram specifically showing a configuration inside a DC-DC power supply of the liquid crystal driver shown in FIG. 3.

FIG. 5 is a circuit diagram specifically showing a configuration inside a DC-DC power supply of a liquid crystal driver according to a third embodiment.

FIG. 6A is a circuit diagram showing a configuration of a DC-DC power supply of a liquid crystal driver according to a fourth embodiment and its surroundings. FIG. 6B is a circuit diagram specifically showing a configuration of an operational amplifier in the DC-DC power supply.

FIG. 7A is a view schematically showing a configuration of a liquid crystal display device according to a fifth embodiment. FIG. 7B is a time chart showing operation of the liquid crystal display device shown in FIG. 7A.

FIG. 8 is a diagram schematically showing a configuration of a conventional liquid crystal display device.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Embodiments 1

Hereinafter, a liquid crystal driver and a method for controlling the driver according to a first embodiment of the present invention will be described with reference to the drawings. FIG. 1 is a diagram schematically showing a configuration of the liquid crystal driver of the first embodiment.

As shown in FIG. 1, the liquid crystal driver of this embodiment includes: a liquid crystal panel 11 including pixels (not shown) arranged in a matrix pattern; a source driver 12 for controlling the gray-scale levels of the respective pixels by applying a voltage to the liquid crystal panel 11; a DC-DC power supply 13 for driving the source driver 12 by supplying current to the source driver 12; a controller 14 for supplying, to the source driver 12, a signal for controlling the gray-scale levels; and a variation calculator 15 for calculating the amount of change in the signal from the controller 14.

Although not shown, in the liquid crystal panel 11, liquid crystal is sandwiched between two opposed electrodes. One of the electrodes is connected to a thin film transistor (TFT). A voltage is applied from the source driver 12 to the source of the TFT for each of the pixels.

The source driver 12 receives signals from the controller 14 and current from the DC-DC power supply 13. The signals from the controller 14 indicate the gray-scale levels of the respective pixels. Specifically, gray-scale-display bits of a signal associated with a pixel which displays white are "All Low" whereas gray-scale-display bits of a signal associated with another pixel which displays black are "All High". The source driver 12 converts these signals into voltages and applies the voltages to the liquid crystal panel 11.

The controller 14 receives a signal of image data from the outside. The controller 14 decodes the signal and supplies, to the source driver 12, signals indicating the gray-scale levels of the respective pixels in the liquid crystal panel 11 and also indicating the timings of displaying the gray-scale levels.

The variation calculator 15 calculates the amount of change in a signal supplied from the controller 14 to the source driver 12. Specifically, when a signal $XN(t)$ for the t^{th} frame (where $t=1, 2, 3, \dots$) is output from the controller 14, the signal $XN(t)$ for the t^{th} frame is compared with a signal $XN(t-1)$ for the $(t-1)^{\text{th}}$ frame which has been held beforehand, thereby calculating how much the number of bits changes between these signals. This amount of change thus obtained is supplied to the DC-DC power supply 13.

The DC-DC power supply 13 receives a signal from the variation calculator 15, determines a current necessary for changing the display on the liquid crystal panel 11 from a display in the $(t-1)^{\text{th}}$ frame to that in the t^{th} frame, and supplies the current to the source driver 12.

Now, a method for controlling the liquid crystal driver according to this embodiment will be described with reference to FIGS. 1 and 2. FIG. 2 is a flowchart showing steps of displaying an image on a liquid crystal panel based on a display pattern according to the first embodiment.

In the control method of this embodiment, as shown in FIG. 2, at step ST1, the signal $XN(t)$ for the t^{th} frame having N bits

is transmitted from the controller 14. The signal $XN(t)$ is generated by decoding image data in the controller 14.

The signal $XN(t)$ is output to the source driver 12 and the variation calculator 15. When the signal $XN(t)$ reaches the source driver 12, the gray-scale voltages for respective pixels are determined at step ST2a. Thereafter, at step ST3a, in the source driver 12, an ability necessary for changing the gray-scale level on the liquid crystal panel is determined for each pixel. Specifically, to change the display on the liquid crystal panel 11 from the gray-scale level in the $(t-1)^{\text{th}}$ frame to the gray-scale level in the t^{th} frame, a voltage needed to be additionally applied to the liquid crystal panel 11 by the source driver 12 is determined. The liquid crystal panel 11 may include pixels whose gray-scale levels do not change. In such a case, it is sufficient to apply a voltage enough to retain the same amount of charge between the electrodes of the pixels.

On the other hand, when the signal $XN(t)$ transmitted from the controller 14 reaches the variation calculator 15, the signal $XN(t)$ and the signal $XN(t-1)$ for the immediately preceding frame are compared at step ST2b, thereby calculating the amount of change. The signal $XN(t-1)$ has been stored in a buffer (not shown) in the variation calculator 15 beforehand. In this case, for a comparison at the output of a signal $XN(t+1)$ for the $(t+1)^{\text{th}}$ frame, the signal $XN(t)$ is stored in the buffer.

Thereafter, at step ST3b, in the DC-DC power supply 13, an ability of the DC-DC power supply 13 necessary for driving the source driver 12 is determined based on the amount of change in a signal. Specifically, a voltage which needs to be supplied to the source driver 12 so as to change the gray-scale level on the liquid crystal panel from the $(t-1)^{\text{th}}$ frame to the t^{th} frame is calculated.

Then, at step ST4, an operational amplifier 41 provided in the DC-DC power supply 13 is controlled, thereby supplying current to the source driver 12. This current includes not only an amount sufficient to charge/discharge the source driver 12 but also an amount sufficient to keep the source driver 12 in a steady state.

Subsequently, at step ST5, the source driver 12 operates.

Then, at step ST6, a display in the t^{th} frame is provided on the liquid crystal panel 11.

Hereinafter, effects obtained in this embodiment will be described in comparison with a conventional device.

In the conventional device, a large constant current I_{max} is supplied from a DC-DC power supply to a source driver. The large current I_{max} herein refers to a current in an amount necessary for driving the source driver at the maximum output. Specifically, the DC-DC power supply constantly supplies a current in an amount capable of being used in such a case that the gray-scale level of every pixel changes greatly. It was believed that such a large current I_{max} is necessary for stabilizing the image on the liquid crystal panel.

On the other hand, in this embodiment, the variation calculator 15 calculates the amount of change of the gray-scale level for every frame. In addition, the DC-DC power supply 13 supplies, to the source driver 12, a current in an amount depending on this amount of the level change. Accordingly, if a change in a display pattern is small, power consumptions of the operational amplifier 41 in the DC-DC power supply 13 and of an operational amplifier (not shown) in the source driver 12 are reduced. On the other hand, if the change in the display pattern is large, a sufficient amount of current is supplied to the source driver 12. That is, the source driver 12 is always capable of applying a voltage with a necessary value to the liquid crystal panel 11. Therefore, in this embodiment, power consumption is reduced without a loss of image quality.

The method of calculating the amount of change in a signal as described in this embodiment is applicable to the following method.

In the liquid crystal panel **11**, the time required for changing the frame is obtained by dividing charge accumulated between two electrodes in the liquid crystal panel **11** by a supplied current, as expressed by the following equation (1):

$$t=Q/I \quad \text{Equation (1)}$$

(where t is time, Q is charge, and I is current).

When the frame changes, the charge changes greatly in a pixel exhibiting a large change of its gray-scale level whereas this change of charge is small in a pixel exhibiting a small change of its gray-scale level. Accordingly, if a constant current is supplied from a DC-DC power supply to a source driver as in the conventional device, the time required for a change of the frame increases as the amount of the change of the gray-scale level increases. If this time differs among pixels, no uniform image quality is obtained.

To overcome the drawback, a method of monitoring the amount of change in a signal for controlling gray-scale level and adjusting the amount of current so as to reduce the difference in the time required for changing the frame is taken. Specifically, current in an amount proportional to the amount of change of the gray-scale level is supplied to each of the pixels. With this method, the time required for changing the frame is uniform among the pixels, thus producing further stabilized displays on the liquid crystal panel. In addition, power consumption is reduced as compared to the conventional device.

This method is applicable to the case of using any one of class-A, B and AB operational amplifiers.

Embodiment 2

Hereinafter, a liquid crystal driver and its operation according to a second embodiment of the present invention will be described with reference to the drawings. FIG. 3 is a diagram schematically showing a configuration of the liquid crystal driver of the second embodiment. FIG. 4 is a circuit diagram specifically showing a configuration inside a DC-DC power supply of the liquid crystal driver shown in FIG. 3.

As shown in FIG. 3, the liquid crystal driver of this embodiment includes: a liquid crystal panel **11** including pixels (not shown) arranged in a matrix pattern; a source driver **12** for controlling the gray-scale levels of the respective pixels by applying a voltage to the liquid crystal panel **11**; and a DC-DC power supply **13** for driving the source driver **12** by supplying current to the source driver **12**.

As shown in FIG. 4, the DC-DC power supply **13** includes: an operational amplifier section **21**; an output transistor section **24** which is connected to the output of the operational amplifier section **21** and in which p-MIS transistors **22(1)** through **22(n)** and n-MIS transistors **23(1)** through **23(n)** at the first through n^{th} stages, respectively, are arranged in parallel; and an I-V converter section **25** including p-MIS transistors **26(1)** through **26(n)** in n stages that are respectively connected to the gates of the p-MIS transistors **22(1)** through **22(n)** in the output transistor section **24**.

The operational amplifier section **21** includes an operational amplifier (not shown).

In the output transistor section **24**, the gate electrodes of the p-MIS transistors **22(1)** through **22(n)** and the n-MIS transistors **23(1)** through **23(n)** in n stages are connected to the output of the operational amplifier section **21**. The source electrodes of the p-MIS transistors **22(1)** through **22(n)**

connected to a power line VCC and the drain electrodes thereof are connected to the drain electrodes of the n-MIS transistors **23(1)** through **23(n)** at their respective stages. The source electrodes of the n-MIS transistors **23(1)** through **23(n)** are connected to a ground line VSS.

A transistor size W and a current I_{DS} flowing between source and drain are in proportion to each other, as expressed by the following equation (2):

$$I_{DS}=(1/2)\mu C_{OX}(W/L)(V_{GS}-V_T)^2 \quad \text{Equation (2)}$$

(where μ =carrier mobility,
 C_{OX} =gate oxide film capacitance,
 W =transistor size,
 L =gate length,
 V_{GS} =gate-source voltage, and
 V_T =threshold voltage)

Accordingly, if the size ratio among the transistors from the first stage to the n^{th} stage is set at 1:2: . . . : n , the ratio of currents flowing in the respective transistors at the first through n^{th} stages in the output transistor section **24** is also determined to be 1:2: . . . : n .

The I-V converter section **25** is provided to control the ON/OFF states of the transistors at the respective stages in the output transistor section **24**. The I-V converter section **25** includes: p-MIS transistors **26(1)** through **26(n)** having the same size as the p-MIS transistors **22(1)** through **22(n)**; resistors **27(1)** through **27(n)** connected to the drains of the p-MIS transistors **26(1)** through **26(n)** at one end and to a ground line VSS at the other end; and inverter sections **28(1)** through **28(n)** in each of which two inverters are connected in series.

The gates of the p-MIS transistors **26(1)** through **26(n)** are connected to the gates of the p-MIS transistors **22(1)** through **22(n)** at their respective stages. The p-MIS transistors **26(1)** through **26(n)** and the p-MIS transistors **22(1)** through **22(n)** form current mirrors at their respective stages. The sources of the p-MIS transistors **26(1)** through **26(n)** are connected to a power line VCC and the drains thereof are respectively connected to the resistors **27(1)** through **27(n)** and the inputs of the inverter sections **28(1)** through **28(n)**.

The resistors **27(1)** through **27(n)** have resistances of $VCC/(I/N)$, $VCC/(2I/N)$, . . . , and $VCC/(nI/N)$, respectively.

In each of the inverter sections **28(1)** through **28(n)**, one of first inverters **29(1)** through **29(n)** and an associated one of second inverters **30(1)** through **30(n)** are connected in series. Each of the inverter sections **28(1)** through **28(n)** has its input connected between the drain electrode of an associated one of the p-MIS transistors **26(1)** through **26(n)** and an associated one of the resistors **27(1)** through **27(n)**. The outputs of the first inverters **29(1)** through **29(n)** are connected to switches **32(1)** through **32(n)**, respectively, and the outputs of the second inverters **30(1)** through **30(n)** are connected to switches **31(1)** through **31(n)**, respectively.

Now, operation of the liquid crystal driver of this embodiment will be described with reference to FIG. 4.

In the output transistor section **24** and the I-V converter section **25**, current from the operational amplifier section **21** flows in the order from the first stage to the n^{th} stage. In this case, the I-V converter section **25** determines to which stage the current flows out of the first through n^{th} stages, in accordance with the amount of the current.

Specifically, when current flows to a p-MIS transistor **22(a)** and an n-MIS transistor **23(a)** at a stage (stage a in this case) out of the first through n^{th} stages, the current also flows into a p-MIS transistor **26(a)** at stage a in the I-V converter section **25** at the same time. In this case, the p-MIS transistor **22(a)** and the p-MIS transistor **26(a)** have the same transistor size and act as a current mirror, so that the same amount of current

flows in these two transistors. The current flowing in the p-MIS transistor 26(a) reaches the input of an inverter section 28(a). If the amount of this current is large, the input signal to a first inverter 29(a) in the inverter section 28(a) is high, the output signal from the first inverter 29(a) is low, and the output signal from a second inverter 30(a) is high. The low-level output from the first inverter 29(a) turns a switch 32(a) OFF and the high-level output from the second inverter 30(a) keeps a switch 31(a) ON, so that current constantly flows in the p-MIS transistor 22(a) and the n-MIS transistor 23(a).

On the other hand, if the amount of a current flowing into the inverter section 28(a) at stage a is small, the input signal to the first inverter 29(a) is low, the output signal from the first inverter 29(a) is high, and the output signal from the second inverter 30(a) is low. The high-level output from the first inverter 29(a) turns the switch 32(a) ON and the low-level output from the second inverter 30(a) turns the switch 31(a) OFF, so that no current flows in the p-MIS transistor 22(a) and the n-MIS transistor 23(a).

Hereinafter, effects obtained in this embodiment will be described in comparison with a conventional device.

In the conventional device, a transistor (output transistor) capable of generating high power is provided at the output of a DC-DC power supply. This transistor is always driven irrespective of a necessary amount of current. If a plurality of transistors are provided, all the transistors are driven.

On the other hand, in this embodiment, the output transistor section 24 and the I-V converter sections 25(1) through 25(n) are provided in the output of the DC-DC power supply to control the ON/OFF states of transistors at respective stages in the output transistor section 24. Accordingly, the amount of current supplied to the source driver is adjusted to an optimum value.

In this case, a current I_S supplied to the source driver is the sum of a current consumed by the source driver itself and a current necessary for charging/discharging the liquid crystal panel. The current I_S is obtained by the following equation (3) when the liquid crystal panel is charged/discharged, and otherwise obtained by the following equation (4):

$$I_S = I_{SO} + I_{PA} \tag{Equation (3)}$$

(where I_S =current needed to be supplied to the source driver,

I_{SO} =quiescent current of the source driver, and
 I_{PA} =current for charging/discharging the panel)

$$I_S = I_{SO} \tag{Equation (4)}$$

The current I_{PA} for charging/discharging the panel is expressed by the following equation (5):

$$I_{PA} = C_{SO} \times |V(t) - V(t-1)| / T \tag{Equation (5)}$$

(where C_{SO} =load capacitance on a source line,
 $V(t)$ =output voltage for the t^{th} frame, and
 T =convergence time)

For example, with respect to a TFT panel, the maximum value of the current I_{PA} for charging/discharging the panel is about 3 to 4 mA whereas the quiescent current I_{SO} of the source driver is 1 mA or less. This shows that the amount of the current I_S necessary for the source driver changes greatly depending on whether the panel is charged/discharged or not. In the case of charging/discharging the panel, the value of the required charging/discharging current I_{PA} changes depending on the amount of change in the display on the panel.

Accordingly, adjustment of the amount of current at every frame change as described in this embodiment enables a large reduction of power consumption. In addition, in this embodi-

ment, current is supplied from current sources (MIS transistors) of the same type to the source driver, resulting in stable displays.

In the foregoing description, the output transistor section 24 and the I-V converter section 25 are constituted by MIS-FETs. Alternatively, according to the present invention, the MISFETs may be replaced with bipolar transistors. In such a case, if the output transistor section 24 is constituted by first through n^{th} stages, n bipolar transistors having emitter areas each occupying one- n^{th} of the total emitter area of all the transistors are provided.

Specifically, the p-MIS transistors 22(1) through 22(n) may be replaced with pnp bipolar transistors. In such a case, the bases of the pnp bipolar transistors are connected to the output of the operational amplifier section 21 and the emitters thereof are connected to a power line VCC. In addition, the n-MIS transistors 23(1) through 23(n) are replaced with npn bipolar transistors. The bases of the npn bipolar transistors are connected to the output of the operational amplifier section 21, the collectors thereof are respectively connected to the collectors of the pnp bipolar transistors, and the emitters thereof are connected to a ground line VSS.

Further, in that case, the p-MIS transistors 26(1) through 26(n) in the I-V converter section 25 are replaced with pnp bipolar transistors. The bases of the pnp bipolar transistors are respectively connected to the bases of the pnp bipolar transistors in the output transistor section 24. The emitters of the pnp bipolar transistors in the I-V converter section 25 and the emitters of the pnp bipolar transistors in the output transistor section 24 are set at the same size. That is, these transistors form a current mirror.

A logic signal of I_S/n is supplied to the base of a bipolar transistor at the first stage and a logic signal of $(n/N)I_S (=I_S)$ is supplied to the base of a bipolar transistor at the n^{th} stage. In the case of using bipolar transistors in such a manner, the same effects are obtained as in the case of using MIS transistors.

This embodiment is applicable to the case of using any one of class-A, B and AB operational amplifiers.

Embodiment 3

Hereinafter, a liquid crystal driver and its operation according to a third embodiment of the present invention will be described with reference to drawings. FIG. 5 is a circuit diagram specifically showing a configuration inside a DC-DC power supply of the liquid crystal driver of the third embodiment. Out of the components of the configuration of this embodiment, detailed description of components already described in the second embodiment will be omitted.

As shown in FIG. 5, the DC-DC power supply of this embodiment includes: an operational amplifier section 21; an output transistor section 24 in which p-MIS transistors 22(1) through 22(n-1) and n-MIS transistors 23(1) through 23(n-1) at the first through (n-1)th stages, respectively, are arranged in parallel; and an I-V converter section 25 including n p-MIS transistors 26(1) through 26(n). The third embodiment is different from the second embodiment in that a current source 33 is provided at the n^{th} stage in the output transistor section 24, instead of the p-MIS transistor 22(n) and the n-MIS transistor 23(n) (shown in FIG. 4). The current source 33 is connected to the gate of the p-MIS transistor 26(n) via a switch 34.

Now, operation of the liquid crystal driver of this embodiment will be described with reference to FIG. 5.

In the output transistor section 24 and the I-V converter section 25, current from the operational amplifier section 21

flows in the order from the first stage to the (n-1)th stage. In this case, the I-V converter section 25 determines to which stage the current flows out of the first through nth stages, in accordance with the amount of the current.

When a current flows to a p-MIS transistor 22(a) and an n-MIS transistor 23(a) at a stage (stage a in this case) out of the first through (n-1)th stages, the current also flows into a p-MIS transistor 26(a) at stage a in the I-V converter section 25 at the same time. In this case, the p-MIS transistor 22(a) and the p-MIS transistor 26(a) have the same transistor size, so that the same amount of current flows in these two transistors to reach the input of an inverter section 28(a). If the amount of this current is large, the input signal to a first inverter 29(a) in the inverter section 28(a) is high, the output signal from the first inverter 29(a) is low, and the output signal from a second inverter 30(a) is high. The low-level output from the first inverter 29(a) turns a switch 32(a) OFF and the high-level output from the second inverter 30(a) keeps a switch 31(a) ON, so that current constantly flows in the p-MIS transistor 22(a) and the n-MIS transistor 23(a).

On the other hand, if the amount of a current flowing into the inverter section 28(a) at stage a is small, the input signal to the first inverter 29(a) is low, the output signal from the first inverter 29(a) is high, and the output signal from the second inverter 30(a) is low. The high-level output from the first inverter 29(a) turns the switch 32(a) ON and the low-level output from the second inverter 30(a) turns the switch 31(a) OFF, so that no current flows in the p-MIS transistor 22(a) and the n-MIS transistor 23(a).

At the nth stage in the output transistor section 24, when the output from an inverter 29(n) becomes high, the switch 34 turns ON, so that current is supplied from the current source 33 toward a source driver (not shown). Accordingly, if a sufficient amount of current is not obtained with the transistors from the first through (n-1)th stages, the current source 33 operates to supply current to the source driver.

In this embodiment, as in the second embodiment, the amount of current is adjusted at every frame change, thus enabling a large reduction of power consumption.

In addition, the current source 33 provides the following advantages.

For example, to generate current by the DC-DC power supply (shown in FIG. 4) of the second embodiment, it is necessary to charge the gate capacitance (C_{OX}) of a high-power transistor provided in the output. Specifically, it is necessary to charge the gate capacitances of the p-MIS transistors 22(1) through 22(n) and the n-MIS transistors 23(1) through 23(n) at the first through nth stages. To charge the gate capacitance, a time τ expressed by the following equation (6) is needed.

$$\tau = CR \tag{Equation (6)}$$

(where C=capacitance near an output transistor and R=time constant)

The capacitance C near the output transistor is expressed by the following equation (7):

$$C = C_{OX} + C_C \tag{Equation (7)}$$

(where C_{OX}=gate capacitance of the output transistor, and C_C=parasitic capacitance of the power line and the output transistor)

On the other hand, in the DC-DC power supply of this embodiment, the current source 33 is provided at the nth stage. Accordingly, if the transistors at the first through nth stages in the output transistor section 24 are driven, current is supplied from the current source 33. The current source 33 starts sup-

plying the current before the gate capacitances of the transistors from the first stage through the (n-1)th stage are completely charged. Accordingly, current is supplied to the source driver quickly, thus enabling high-speed operation. This is especially effective in a case where the image on a liquid crystal panel changes rapidly.

This embodiment is applicable to the case of using any one of class-A, B and AB operational amplifiers.

Embodiment 4

Hereinafter, a liquid crystal driver and its operation according to a fourth embodiment of the present invention will be described with reference to drawings. FIG. 6A is a circuit diagram showing a configuration of a DC-DC power supply of the liquid crystal driver of the fourth embodiment and its surroundings. FIG. 6B is a circuit diagram specifically showing a configuration of an operational amplifier in the DC-DC power supply.

As shown in FIG. 6A, the liquid crystal driver of this embodiment includes: a DC-DC power supply 13; and a comparator 44 provided in parallel with an operational amplifier 41 provided in the DC-DC power supply 13.

The output of the operational amplifier 41 is fed back to the input, i.e., negative feedback, via a node 43 between the operational amplifier 41 and an output terminal 42. The (+)-side input of the operational amplifier 41 is connected to the (-)-side input of a comparator 44 via a variable resistor 45. One end of the variable resistor 45 which is not connected to the operational amplifier 41 is grounded. The (+)-side input of the comparator 44 is connected to the output terminal 42.

As shown in FIG. 6B, an operational amplifier section 46, p- and n-MIS transistors 47 and 48 serving as output transistors of the operational amplifier section 46, and a p-MIS transistor 49 for supplying a high/low signal to the gate electrode of the p-MIS transistor 47 are provided in the operational amplifier 41. The gate electrode of the p-MIS transistor 49 is connected to the output of the comparator 44.

Now, operation of the liquid crystal driver of this embodiment will be described with reference to FIGS. 6A and 6B.

In a circuit with a positive power supply, the lower limit of a desired value (standard value) of the output voltage from the operational amplifier section 46 is generally set at V_x-α where V_x is a theoretically-desired value of the output voltage and α is a value which is determined in consideration of the driving temperature and variations among devices. If the output from the operational amplifier is V_x-α or higher, a source driver (not shown) does not operate normally.

In this embodiment, a voltage of V_x-α is applied to the (-)-side input of the comparator 44. The value of V_x-α is obtained by adjusting the value of the variable resistor 45 with the variable resistor 45 interposed between the (+)-side input of the operational amplifier 41 and the (-)-side input of the comparator 44. On the other hand, since the (+)-side input of the comparator 44 is connected to the output terminal 42, the output voltage of the operational amplifier 41 is applied to the (+)-side input of the comparator 44.

The comparator 44 compares V_x-α and the output voltage of the operational amplifier, and outputs a resultant signal Sig4 to the p-MIS transistor 49 in the operational amplifier 41. The p-MIS transistor 49 controls operation of the operational amplifier based on the signal Sig4. Specifically, if the output voltage of the operational amplifier 41 is V_x-α or higher, operation of the operational amplifier is stopped, whereas if the output voltage of the operational amplifier 41 is lower than V_x-α, operation of the operational amplifier is started again.

Hereinafter, effects obtained in this embodiment will be described in comparison with a conventional device.

In a conventional device, irrespective of the amount of a current flowing into the source driver, the operational amplifier always operates. Accordingly, self-power consumption of the operational amplifier is high. It was believed that if the operation of the operational amplifier stops, the output voltage thereof drops.

On the other hand, in this embodiment, if the output from the operational amplifier **41** is within the range of the standard value, the operational amplifier is temporarily stopped, thereby reducing power consumption. If the output from the operational amplifier **41** is less than the standard value, the operational amplifier is started again, so that sufficient current is always supplied to the source driver. Accordingly, a stable display is maintained without deterioration in characteristics of the operation of the source driver.

The foregoing description has been made using a power supply for driving a source driver as an example. Alternatively, the present invention is applicable to other power supplies such as power supplies used for a counter electrode and a common electrode. In such a case, power consumption is reduced without a loss of image quality.

In the foregoing description, the positive power supply is used. However, the present invention is applicable to a negative power supply. In such a case, the comparator compares the maximum value $V_x + \alpha$ of the standard value with the output voltage from the operational amplifier. If the output voltage of the operational amplifier is $V_x + \alpha$ or lower, the operational amplifier is stopped, whereas if the output voltage is higher than $V_x + \alpha$, the operational amplifier is operated. Accordingly, power consumption is also reduced without deterioration in characteristics of the display and the like.

This embodiment is applicable to the case of using any one of class-A, B and AB operational amplifiers.

Embodiment 5

Hereinafter, a liquid crystal driver and its operation according to a fifth embodiment of the present invention will be described with reference to drawings. FIG. 7A is a view schematically showing a configuration of the liquid crystal display device of the fifth embodiment. FIG. 7B is a time chart showing operation of the liquid crystal display device shown in FIG. 7A.

As shown in FIG. 7A, the liquid crystal display device of this embodiment includes: a TFT liquid crystal panel **51**; a gate driver **52** equipped with a DC-DC power supply and connected to a gate line (not shown) of the liquid crystal panel **51**; and a source driver **53** equipped with a RAM controller and connected to a source line (not shown) of the liquid crystal panel **51**.

In the liquid crystal panel **51**, an upper electrode **54** and a lower electrode **55** are provided opposed to each other to form a capacitor. The upper electrode **54** is connected to the drain of a thin film transistor (TFT) **56**. The source of the TFT **56** receives a voltage from the source driver **53**. The gate of the TFT **56** receives a voltage from the gate driver **52**. On the other hand, the lower electrode **55** receives a voltage from the DC-DC power supply incorporated in the gate driver **52**.

The liquid crystal panel **51** includes source lines (not shown) connected to 132 RGB filters and 176 gate lines.

Although not shown, an operational amplifier for amplifying an input voltage and a booster connected to the operational amplifier are provided in the DC-DC power supply. The

booster is provided to boost a reference voltage supplied from the outside and to supply the boosted voltage to the operational amplifier.

Now, operation of a liquid crystal driver according to this embodiment will be described with reference to FIG. 7B.

As shown in FIG. 7B, a clock signal CKV is always supplied from the RAM controller incorporated in the source driver **53** to the DC-DC power supply. At every frame, 300 clocks are supplied to the DC-DC power supply. During the supply from the first clock through the 176th clock associated with the 176th gate line out of the 300 clocks, image data is written in the liquid crystal panel. This period during which write operation is actually performed in this manner will be referred to as an effective write period. Then, from the 177th clock through the 300th clock, no image data is written in the liquid crystal panel. This period during which write operation is not actually performed will be referred to as a blanking period.

During the blanking period, the frequency of a clock signal supplied to the booster in the DC-DC power supply is 1/N times (where N=2, 3, 4, . . .) as high as that during the effective write period.

A signal STV is a signal for controlling the time at which the first clock is input. Specifically, when the blanking period for a frame terminates and the display changes to the next frame, the signal STV is supplied from the controller to the gate driver.

A signal NOEV is a signal for preventing overlapping between the times of inputs of clocks associated with respective gate lines. The signal NOEV is supplied to the gate driver for each of the first through 176th clocks.

During the blanking period, a power supply control signal PSAVE is supplied from the controller to the DC-DC power supply. The supply of the power supply control signal PSAVE continues from the rising edge of the 177th clock in a frame to the rising edge of the first clock in the next frame. The power supply control signal PSAVE causes the operational amplifier in the DC-DC power supply to stop and to be in a High-Z state.

In this embodiment, during the blanking period, the operational amplifier in the DC-DC power supply is stopped and the frequency of a clock signal supplied to the booster is reduced. Accordingly, power consumption is reduced, as compared to a conventional device in which constant power is supplied even during the blanking period. Hereinafter, this will be described specifically.

In the conventional device, a power consumption P of a DC-DC power supply is expressed by the following equation (8):

$$P = P_{opa} + P_{ch} + P_{etc} + P_{icd} \quad \text{Equation (8)}$$

(where P_{opa} = power consumption of the operational amplifier,

P_{ch} = power consumption of the booster,

P_{etc} = power consumption of another circuit, and

P_{icd} = power consumption necessary for charging/discharging the liquid crystal panel)

The power consumption P_{icd} is expressed by the following equation (9):

$$P_{icd} = CVf \quad \text{Equation (9)}$$

(where C = panel capacitance,

V = voltage applied to the panel, and

f = frequency of a clock signal supplied to the panel)

On the other hand, in this embodiment, the power consumption P of the DC-DC power supply is expressed by the following equation (10):

$$P = P_{opa} \left\{ \frac{(T-t_1)}{T} \right\} + P_{ch} \left\{ \frac{(T-t_1)}{T} \right\} + P_{ch} \left(\frac{t_1}{T} \right) \cdot \left(\frac{1}{N} \right) + P_{etc} + P_{icd} \left\{ \frac{(T-t_1)}{T} \right\} \quad \text{Equation (10)}$$

(where T =total period (the sum of the effective write period and the blanking period),

t_1 =blanking period, and

$1/N$ =division ratio of the clock frequency of the booster during the blanking period to the clock frequency of the booster during the effective write period)

In this manner, power consumptions of the operational amplifier and the booster during the blanking period are reduced. Both the operational amplifier and the booster are analog circuits. In the conventional device, the power consumption P_{opa} of the operational amplifier, the power consumption P_{ch} of the booster, and the power consumption P_{icd} necessary for charging/discharging the panel occupy a large part of the total power consumption P of the DC-DC power supply. However, in this embodiment, power consumption of a charging/discharging current in such an operational amplifier, a booster and a panel exhibiting high power consumption is reduced, thus obtaining significant effects. In addition, the operation of the operational amplifier is stopped during the blanking period, so that no drawbacks occur in image quality.

The foregoing description has been made using a power supply for driving a source driver for driving a counter electrode or a common electrode, as an example. Alternatively, the present invention is applicable to other power supplies such as a power supply used for driving a gate driver. In such a case, power consumption is reduced without deterioration in characteristics of the display and the like.

What is claimed is:

1. A liquid crystal display device, comprising:
 - a display section for displaying an image;
 - a driver circuit for supplying an output signal for driving the display section;
 - a controller circuit for supplying, to the driver circuit, a signal for controlling the output signal;
 - a variation calculator for calculating the amount of change in the signal; and
 - a power supply circuit for supplying, to the driver circuit, power with a value based on the amount of change in the signal,
 wherein the power supply circuit adjusts the amount of a current supplied to the driver circuit, in accordance with the amount of change in the signal.
2. The device of claim 1, wherein a plurality of pixels are provided in the display section,
 - the driver circuit applies, to the pixels, a voltage depending on the output signal,
 - the variation calculator calculates the amount of change in the signal for each of the pixels, and
 - the power supply circuit supplies, to the driver circuit, a current in an amount proportional to the amount of change in the signal.
3. A power supply circuit, comprising:
 - an operational amplifier;
 - an output transistor section including output transistors in a plurality of stages connected to an output of the operational amplifier;
 - an I-V converter circuit including a transistor forming a current mirror together with an associated one of the output transistors; and
 - a switching circuit for controlling an ON/OFF state of an associated one of the output transistors based on an

output signal from the I-V converter circuit, the switching circuit being connected to the I-V converter circuit and the output transistor section.

4. The circuit of claim 3, wherein the I-V converter circuit further includes:

a resistor connected to the transistor in the I-V converter and a ground line; and

an inverter section including a plurality of inverters, the inverter section having an input connected between the transistor in the I-V converter and the resistor and an output connected to the switching circuit.

5. The circuit of claim 4, wherein the output transistor section includes, as the output transistors:

p-MIS transistors in the plurality of stages, each of the p-MIS transistors having a gate connected to the output of the operational amplifier and a source connected to a power line; and n-MIS transistors in the plurality of stages, each of the n-MIS transistors having a gate connected to the output of the operational amplifier, a drain connected to a drain of an associated one of the p-MIS transistors, and a source connected to a ground line, and the transistor in the I-V converter circuit is a p-MIS transistor of the same size as that of an associated one of the p-MIS transistors in the output transistor section.

6. The circuit of claim 4, wherein the output transistor section includes, as the output transistors:

pnp bipolar transistors in the plurality of stages, each of the pnp bipolar transistors having

a base connected to the output of the operational amplifier and an emitter connected to a power line; and

nnp bipolar transistors in the plurality of stages, each of the npn bipolar transistors having a base connected to the output of the operational amplifier, a collector connected to a collector of an associated one of the pnp bipolar transistors, and an emitter connected to a ground line, and

the transistor in the I-V converter circuit is a pnp bipolar transistor having an emitter of the same size as that of an associated one of the pnp bipolar transistors, which is at the same stage, in the output transistor section.

7. The circuit of claim 3, wherein a current source is connected to the output transistor section.

8. A liquid crystal display device, comprising:

a display section for displaying an image;

a power supply circuit for supplying power for controlling the image on the display section, the power supply circuit including an operational amplifier;

a comparator for comparing an output from the operational amplifier with a standard value; and

a switching section for controlling an ON/OFF state of the operational amplifier based on an output signal from the comparator.

9. The device of claim 8, wherein the operational amplifier includes a side input, a (-)-side input and an output,

the comparator includes a (+)-side input, a (-)-side input and an output, the (+)-side input of the comparator is connected to the output of the operational amplifier,

the (-)-side input of the comparator is connected to the (+)-side input of the operational amplifier,

the output of the comparator is connected to the switching section; and

a resistor is interposed between the (-)-side input of the comparator and the (+)-side input of the operational amplifier.

10. A liquid crystal display device, comprising:

a display section for displaying an image;

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a power supply circuit including an operational amplifier for supplying power for controlling the image on the display section, and
 a controller circuit for generating a signal for controlling the image on the display section,
 wherein the operational amplifier is stopped during a blanking period, and the operational amplifier is stopped based on the signal from the controller circuit during the blanking period.

11. The device of claim 10, wherein the power supply circuit further includes a booster for boosting a voltage to be supplied to the operational amplifier,
 a clock signal is supplied from the controller circuit to the booster, and
 the frequency of the clock signal in the blanking period is lower than that in an effective write period.

12. The device of claim 10, wherein the display section includes an upper electrode, a lower electrode opposed to the upper electrode, a source line connected to the upper electrode, a gate line connected to the upper electrode, and a transistor connected to both the source line and the gate line, and
 the liquid crystal display device further comprises:
 a source driver for driving the source line, the source driver being connected to the transistor; and
 a gate driver for driving the gate line, the gate driver being connected to the transistor.

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13. The device of claim 12, wherein the power supply circuit supplies the power to either the source driver or the gate driver.

14. The device of claim 12, wherein the power supply circuit supplies the power to the lower electrode.

15. A method for controlling a liquid crystal display device including a display section, a driver circuit for supplying a voltage to the display section, a controller circuit for supplying, to the driver circuit, a signal for controlling the voltage, and a power supply circuit for supplying power to the driver circuit, the method comprising:
 a first step of calculating the amount of change in the signal from the controller circuit; and
 a second step of supplying power from the power supply circuit to the driver circuit based on the amount of change in the signal,
 wherein in the second step, the amount of a current supplied to the driver circuit is adjusted in accordance with the amount of change in the signal.

16. The method of claim 15, wherein a plurality of pixels are provided in the display section,
 in the first step, the amount of change in the signal is calculated for each of the pixels, and
 in the second step, a current in an amount proportional to the amount of change in the signal is supplied to the driver circuit.

* * * * *

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摘要(译)

根据本发明的液晶显示装置包括：液晶面板11；源极驱动器12，用于通过向液晶面板11施加电压来控制灰度级；DC-DC电源13，用于通过向源极驱动器12提供电流来驱动源极驱动器12；控制器14，用于向源极驱动器12提供用于控制灰度级的信号；用于计算来自控制器14的信号的变化量的变化计算器15。在DC-DC电源13中，要提供给源极驱动器12的电流根据由信号计算的信号的变化量而变化。变化计算器15。

