Plasma Addressed Liquid Crystal Display

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Abstract

We have demonstrated the two types of 42 inch Plasma Addressed Liquid Crystal (PALC) display at various exhibitions including the Japan Electronics Show '98. First type is suitable for VGA, and second type is suitable for HD. We have developed the Axially Symmetric aligned Micro-cell Mode (ASM) technology in order to achieve wide viewing angle of PALC display. The PALC display has many advantages such as wide viewing angle, high contrast, high brightness, and low power consumption, over the other large-sized flat panel displays.
This paper reports the characteristic of PALC display, relevant technology, and the block diagram of PALC display system.

Introduction

The world is changing from the age of home electric appliances to the age of personal appliance where we have own televisions, personal computers, cellular phones and the portable terminals. In the new era, information is instantaneously exchanged through the network in the individual, the home, the enterprise, the country, and the world. What kind of display is required at the Information Networked Age? In the television, displays capable to correspond to various reflection formats reproducing the feeling of presence are required, while personal computers need displays of the ultra high density by which a lot of information can be displayed gently to eyes at a time, and thin type, small size, and low power consumption displays are demanded for cellular phones and portable terminals. Manufacturers in the world on a large screen display are facing technical difficulties like lightening, making to low power consumption in addition to the performance improvement of the quality and the resolution, and the price cutting, etc. In order to solve these difficulties, displays of various methods are being proposed.
The Plasma Addressed Liquid Crystal display is an active matrix type liquid crystal display of the hybrid structure utilizing the plasma for switching and the liquid crystal for the display part. Making the best use of combining characteristic of plasma cell which is comparatively cheap and easily enlarged, and liquid crystal of high quality display, it is expected much as large scale, plane display of high quality and high resolution. It has been now developed jointly by three manufacturers, Sharp, Sony and Philips.
We will explain the principle, the structure, the feature, the problem to be overcome, the ultra high density techniques and the system configuration of prototypes, based on 42-inch Plasma Addressed Liquid Crystal Display developed by three manufacturers.

1. Panel structure and principle

1.1 Panel structure

Fig. 1 shows the structure of the Plasma Addressed Liquid Crystal Panel. The plasma cells is on a glass substrate with the rib of about 200µm in height forming a long and slender ditch covered by the thin board glass of about 50µm in thickness welded with the low melting point glass making a channel space. In the channel space,

cathode/anode electrode are placed and filled with rare gas at the pressure of several kPa for plasma discharge. As for the liquid crystal cell, the liquid crystal is injected into the space of several μm between the color filter made of the ITO transparent film on which the column electrode for the signal input is formed and the thin board glass. The polarizer is put before and behind the Plasma Addressed Liquid Crystal Panel, and the backlight is set up in the rear side.

1.2 Operation Principle

The switching is performed by the plasma instead of TFT though it is similar to a usual liquid crystal for the operation principle of the liquid crystal cell as the display element. Incidence light from the backlight is adjusted to be a straight line polarized light by the polarizer, and the gray scale is added by modulated with the liquid crystal. The full color is displayed by passing the color filter and the polarizer in addition.

The operation of the plasma cell as the switching element shall be explained below. **Fig. 2** explains switch operation of the Plasma Addressed Liquid Crystal Panel and the TFT liquid crystal display panel as the comparison of the switching operation. **Fig. 3** shows the driving wave form and the timing chart of the Plasma Addressed Liquid Crystal Panel.

First of all, it is necessary to discharge the plasma channel to write data. When plasma voltage V_P (-350V approx.) is applied to the cathode based on the electric potential of the anode, the rare gas enters the state of the electrical discharge in several μs. At this time, the electric potential in the plasma channel under the electrical discharge becomes almost an anode electric potential excluding the cathode neighborhood, and enters in the state that the anode and the virtual electrode short circuited electrically are generated on the thin board glass. When comparing with the transistor, it is verified that the values of cathode and gate, anode and source, and virtual electrode and drain are respectively equivalent. Next, when signal voltage V_C (70V approx.) is applied to the column electrode of the data line for this state of the electrical discharge, the potential difference between the virtual electrode on the thin board glass and V_C enters the state applied to the liquid crystal and the thin board glass, which allows the writing to the liquid crystal. After the electrical discharge is completed, since the inside of the plasma cell of each pixel becomes insulated state and maintains the state to the following electrical discharge begins, it is possible to perform memory ON state of the liquid crystal. This makes it possible to scan each scanning line with one long plasma channel as long as a horizontal plasma line is separated.

In order to write correct data, it is necessary to make the amount of the plasma of the space charge smaller than the data maintenance time by V_C in **Fig. 3**, and V_P starting down time smaller than the attenuation time of amount of

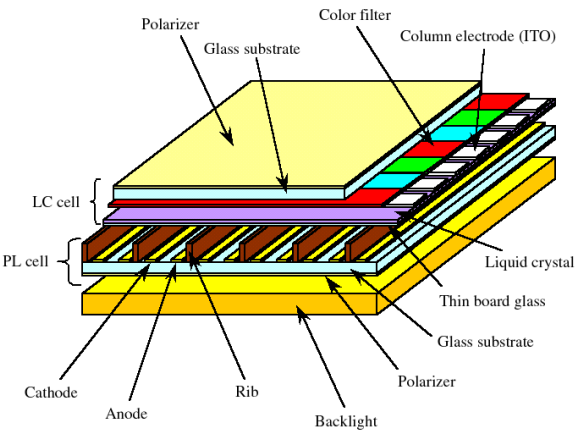

Fig. 1 Schematic structure of PALC panel.

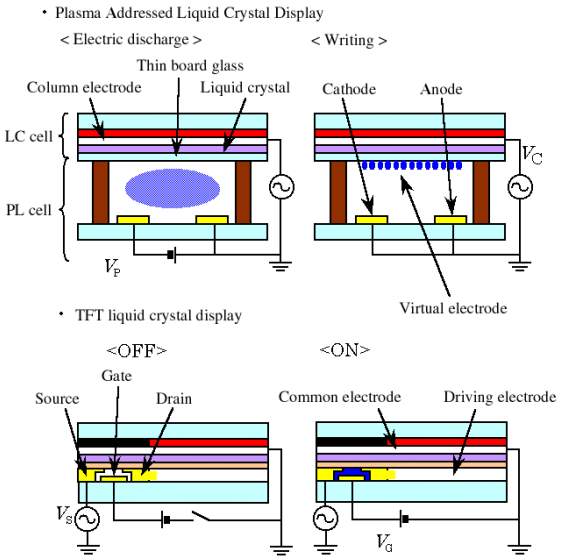

Fig. 2 Explanation figure of switch operation, PALC panel and TFT panel.

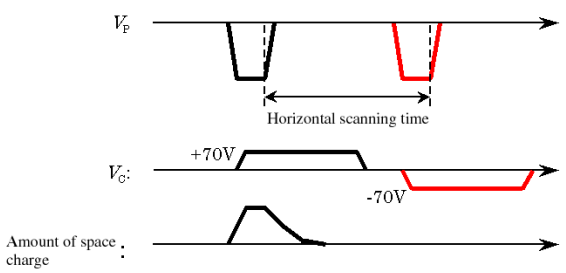

Fig. 3 Driving waveform & Timing chart.

the space charge. Also, a series of operation should be completed within one horizontal scanning time.

2. Features and problems to be overcome

Because the Plasma Addressed Liquid Crystal Panel is a combination of the plasma cell and the liquid crystal cell, the merit and the weak point of PDP and the liquid crystal panel have been succeeded as shown in **Fig. 4**.
Since less cleanness is required to fabricate the plasma cell of the Plasma Addressed Liquid Crystal Panel than that of the liquid crystal panel, it is possible to apply the print method with a low minuteness degree of the manufacturing process and easier to make a large size substrate. In addition, it has the feature of not causing the point defect on the structure. However, the thin glass substitute which separates the plasma cell and the liquid crystal cell plays an important role on the structure of the Plasma Addressed Liquid Crystal Panel and it has the electrical relation between the liquid crystal and the thin board glass as shown in **Fig. 5**.

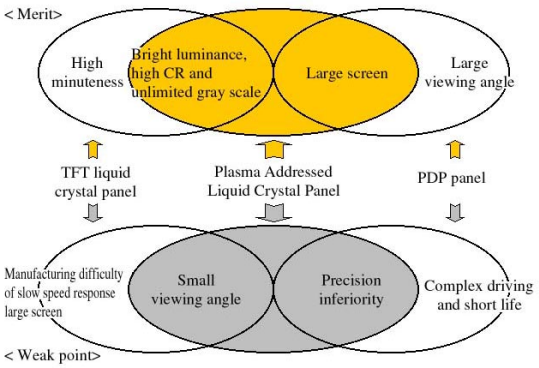

Fig. 4 Merits and demerits of PDP panel and liquid crystal panel.

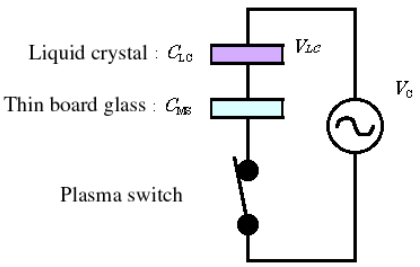

Fig. 5 Electrical relation between liquid crystal and thin board glass.

The relation of high pressure signal voltage V_C applied to the column electrode and V_{LC} voltage applied to the liquid crystal is, where the electric capacity of the liquid crystal and the thin board glass is C_{LC}, C_{MS}, the dielectric rate is ε_{LC}, ε_{MS} and the thickness is d_{LC} d_{MS},

$$V_C = V_{LC} \times \{(C_{LC} + C_{MS}) / C_{MS}\}$$
$$= V_{LC} \times \{(1 + \varepsilon_{LC} \cdot d_{MS} / \varepsilon_{MS} \cdot d_{LC}\}$$

shall be formed. Because it is not possible to drastically change ε_{LC}, ε_{MS} and d_{LC}, the thickness of the thin board glass must be minimized in order to suppress V_C. The change of the board thickness changes the voltage applied to the liquid crystal, which causes an irregular display and requires tight control. About the gas introduced in the plasma channel, various examinations are performed for a high speed switching and the electrical discharge voltage decrease. A high quality image can be displayed by optimizing the kind of gas and the gas pressure.
Because the source of light of the Plasma Addressed Liquid Crystal Panel is a backlight, and it can be designed separately, a high luminance can be facilitated. Thanks to the liquid crystal cell property that the analog modulation can be performed, the image of a high gray scale and high contrast is obtainable. As for the color reproducibility, a high chroma is obtained by optimizing the color filter. Thus, the freedom of the design is high because each element handling the high resolution is individually divided into the plasma side and the liquid crystal side. The liquid crystal, however, had the problem with a narrow viewing angle. The axially symmetric aligned micro-cell mode (ASM), large viewing angle technology which was a new alignment technology was developed while various methods were proposed to the viewing angle characteristic improvement of the liquid crystal. **Fig. 6** explains the ASM technology.

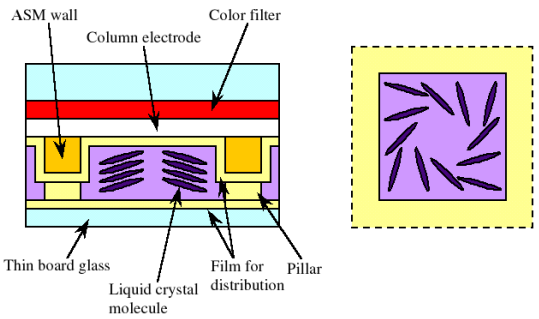

Fig. 6 Technology of large viewing angle

This method does not stay only in the view corner improvement, and have the advantage that the rubbing process and the spacer scatter process are unnecessary from the liquid crystal assembly process. As for the structure, the pillar which is the ASM wall and the spacer for the ASM distribution on the color filter is formed, and the ITO

electrode wall, the pillar, and the thin board glass on which the film for the distribution are formed in which the liquid crystal is injected. This method achieves the display property of uniformity and the large viewing angle in a wide area.

Fig. 7 shows ASM distribution when voltage is applied and **Fig. 8** shows comparison of viewing angles of ASM liquid crystal and TN liquid crystal which were measured in contrast ratio 10:1.

We have developed 42-inch Plasma Addressed Liquid Crystal Display and have exhibited it in the electronics show in 1997. For the electronics show of held in the succeeding year, an improved prototype was exhibited. The improvements include; 30% permeability by optimizing the development of the new wall material assisted for the distribution and the structure, newly designed plasma partition, improvement of the aperture rate, and about 1.5 times high brightness (at the same power consumption) by adopting a highly effective backlight compared with the former panel for 42-inch VGA.

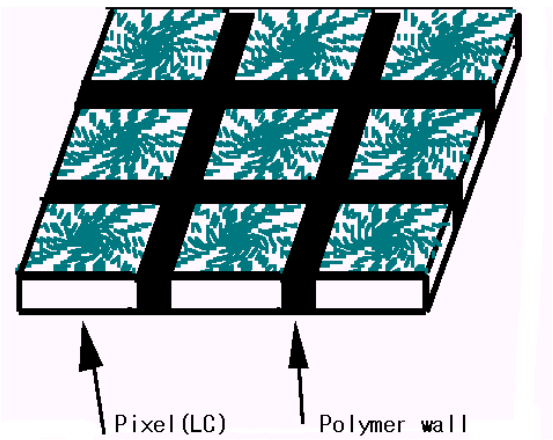

Fig. 7 Model of ASM cells.

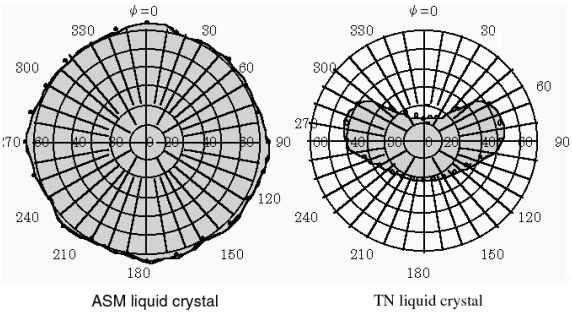

Fig. 8 Comparison of viewing angle characteristics.

3. System Configuration

Fig. 9 shows the system configuration of the Plasma Addressed Liquid Crystal Display. The system consists of the main body of the panel, the data side liquid crystal driver, the scanning side plasma driver, the driver controller, the picture signal processing, and the backlight. The panel is of a simple matrix structure and data are written in the liquid crystal in order of the line. The digital data of the image are assigned to the data liquid crystal drivers on upper or lower driver substrate between adjacent pixels and are applied to the liquid crystal layer after converted to about 70V analog voltage. The gamma characteristics of the liquid crystal and the image is corrected when an analog voltage in driver IC is converted. The scanning side plasma driver discharges about 350V between the anode cathodes, and is a standard electric potential at writing of the anode voltage data in the liquid crystal layer. The liquid crystal AC drive of a low cross talk has been achieved without raising the voltage of the liquid crystal driver by using the time of almost 1/3 at one horizontal period for an electrical discharge period and reversing the anode electric potential in line and field.

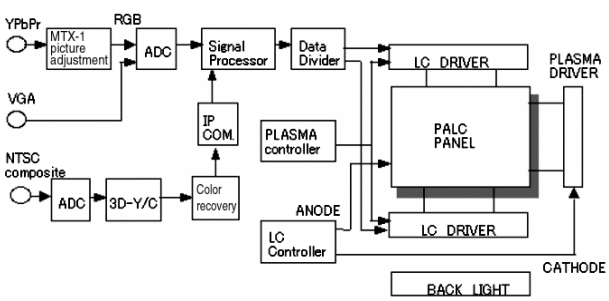

Fig. 9 Block diagram of PALC display system.

In the image signal processing part, the format conversion and the picture quality adjustment are made in relation to panel resolution (854 x RGB x 480) corresponding to VGA and a wide VGA input of the PCs and composite, S input, and the color difference input of YPbPr of HD and NTSC. When HD input, digital images of two dimensional filter and three dimensional enhance, etc. are adjusted after image adjustment and digitalization by converting YPbPr signal to the RGB. The NTSC composite signal is converted to the progressive scanning after

three dimension YC separation, the color recovery, and digitalization and aims at the improvement of the display characteristic. For the NTSC signal, it is possible to display two both sides, and the image such as the zoom screens could be displayed. The PC input performs the compensation by DSP according to the source and the display mode of the input. The majority of these image signal processing parts and liquid crystal and plasma driver's control parts are composed of FPGAs and the programmable devices of processor type.

An aluminum chassis, effective to EMI measures, was used to lighten and to suit both wall hanging and table top installation. The highly effective backlight newly developed was adopted for high brightness and effectiveness and lower power consumption was attained.

The AC waveform is always monitored and whenever the power supply stops momentarily, the circuit which monitors panels, circuits, power supply, temperature and backlight, etc. is provided for protection.

Fig. 10 shows the appearance and the specifications of the Plasma Addressed Liquid Crystal Display exhibited at the electronics show in 1998.

6. High minuteness technology

The high minuteness technology of the Plasma Addressed Liquid Crystal Panel shall be explained.

We have succeeded in doubling the number of vertical lines in keeping almost similar electrode structure to VGA, by controlling the electrical discharge by twice detailed by using the feature of the Plasma Addressed Liquid Crystal which is used a slight plasma electrical discharge for the switching. **Fig. 11** shows the explanation chart. Utilizing the color filter technology of the liquid crystal, the number of pixels of parallel directions as many as 1920 pixels is attained. The HD image signal at twice faster speed is processed in the image processing. Moreover, the interpolation processing is optimized, and the display of the progressive method which does not flicker has been achieved. For the upcoming information networked age, the high density Plasma Addressed Liquid Crystal Display required for HD has been developed by achievement of this horizontal/vertical direction high minuteness and the above mentioned image processing.

Fig. 12 shows the appearance and the specification of the Plasma Addressed Liquid Crystal Display respondent to HD high minuteness, exhibited at Electronics Show in 1998.

Conclusion

Screen size	42 inch (933.1 x 524.2 mm)
Aspect ratio	16 : 9
Resolution	854H X 3 X 480V
Scanning method	Progressive method
Dot pitch	0.364 X 1.092mm
Dot display color	16,700,000 colors
Luminance	400 cd/m² (all white screen)
View corner	160° H - 140° V
Discernment room contrast	120:1(@300lux)

Fig. 10 Exterior and performance of 98JES 42inch PALC display.

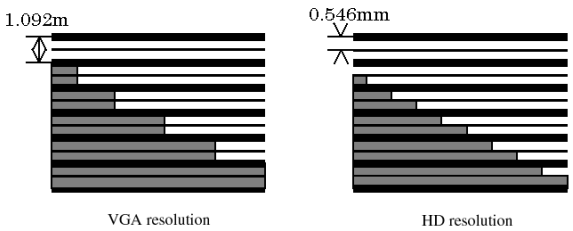

Fig. 11 High minuteness technology.

Screen size	42 inch (933.1 x 524.2 mm)
Aspect ratio	16 : 9
Resolution	1920H X 3 X 960V
Scanning method	Progressive method
Dot pitch	0.162 X 0.546mm
Dot display color	16,700,000 colors
Luminance	350 cd/m² (all white screen)
View corner	160° H - 140° V
Discernment room contrast	100:1(@300lux)

Fig. 12 Exterior and performance of 98JES HD PALC display.

42-inch large viewing angle Plasma Addressed Liquid Crystal Display obtained a high reputation to its contrast ratio in a large viewing angle, a large screen, and a high contrast ratio at the bright environment, at various exhibitions including Electronics Show in 1997 and in 1998. It has been always shown at Shin-Osaka Station, JR West Japan since December, 1998.

In order to penetrate into homes as a wall hanging TV, it must be at the low price, low power consumption, large screen, thin and light. Also, it should be required in the market of the digital broadcasting age and the information networked age. The Plasma Addressed Liquid Crystal Display is composed of plasma cell and liquid crystal cell. It makes the best use of the merit of each cell to its maximum, and has the features of high brightness, high contrast, and the large viewing angle. It is also possible to use the point where the freedom of the design is very high, and to implement the new liquid crystal technology for future development. It has been convinced that the Plasma Addressed Liquid Crystal Display shall be a powerful display method for both homes and business, bearing the responsibility of a large screen FPD market as the main display device in the information network age.

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