A General Performance of PSS-LCDs

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Abstract

In this paper, a general performance of the PSS-LCD or Polarization Shielded Smectic Liquid Crystal Display is discussed. This smectic base LCD does not use any spontaneous polarization, but uses induced polarization just same with current nematic base LCDs. Specific initial molecular alignment as well as specific cell design realizes extremely fast optical response speed with native wide viewing angle. Moreover, this performance is provided by full compatible electronics for current conventional LCDs. A general performance of the PSS-LCD is introduced here.

1. Introduction

In last decade, TFT base LCDs have demonstrated significant progress in terms of an advanced flat panel display. MVA mode LCDs (1), IPS mode LCDs (2), FFS mode LCDs (3) and OCB mode LCDs (4) are results of those efforts. Their contrast ratio is now over 600:1 with faster optical response speed than ever; moreover, their viewing angle is now competing with that of an emissive FPD. On the other hand, above great success has provided other types of challenge to the LCD industry. In particular, both optical response speed and viewing angle have been realized under the some sacrifices both in characteristic properties of liquid crystal physics and volume manufacturing payload.

In last decade, parallel to the above tremendous success of the TFT base new types of LCD modes, several unique approaches have been of our acknowledges such as ferroelectric LCDs (5), anti-ferroelectric LCDs (6) those are attempting to have much faster optical response speed with native wider viewing angle. Unfortunately, those approaches so far have not shown a great success in terms of industrial point of view.

This paper introduces a new approach in the LCD mode succeeding to last three decades of inheritance from conventional LCDs with newly invested fast optical response speed and native wide viewing angle.

2. The PSS-LCD

The PSS-LCD or Polarization Shielded Smectic Liquid Crystal Display uses a certain types of smectic liquid crystal molecules in conjunction with very strong azimuthal anchoring energy. Its driving torque is provided by a coupling between applied electric field and induced polarization from liquid crystals. In this sense, the PSS-LCD would be classified in conventional LCD drive mode in terms of its driving source. Although the PSS-LCD requires using a certain types of smectic liquid crystal materials, it does not use any spontaneous polarization at all. Due to the torque source, the PSS-LCD has exactly same V-T capability with most of nematic base LCDs such as analog gray scale with a certain threshold property.

3. Drive mode of the PSS-LCD

3.1 Principle of the PSS-LCD

Figure 1 illustrates a general description of the PSS-LCD. The smectic liquid crystal molecules have an initial molecular alignment along with set alignment direction in their n-directors. A pair of linear polarizers is set as cross Nicole position. Usually, the PSS-LCD is used as a normally black mode. Therefore, the initial molecular alignment quality is very important to obtain higher contrast ratio same with an IPS-LCD and an FFS-LCD.

The liquid crystal molecular movement is not like most of nematic base LCDs. The PSS liquid crystal molecules move along with cone surface shown in Figure 1. The tilt direction of the molecule is decided by direction of the applied electric field, b\not by polarity of the applied field. Therefore, the PSS-LCD is fully compatible with current conventional drive scheme with nematic base LCDs. Every time the applied electric field changes its direction by frame inversion, line inversion, or dot inversion whatever, the PSS-LC molecules move along with the cone surface with passing through the top of the cone. Thus, a typical light throughput behavior to the time base of the PSS-LCD is such like in Figure 2. This automatic blanking function of the PSS-LCD is one of its unique properties. Typical optical response time of the PSS-LCD is 150 μs in rise process, and 80 μs in decay process. This faster decay time than rise time is also one of the unique characteristic properties of the PSS-LCD.

The native wide viewing angle has been provided by the PSS-LCD's molecular switching configuration as well as its extremely fast optical switching. As illustrated in Figure 1, the PSS-LCD's molecular switching configuration is similar with IPS-LCDs and FFS-LCDs. Moreover, the extremely fast optical switching of the PSS-LCD realizes the time domain averaging in the birefringence. Unlike conventional LCDs, the PSS-LCD decides its birefringence dynamically with time range of frame inversion, line inversion or dot inversion. This dynamic birefringence mode makes time domain averaging in birefringence. Thanks to an extremely fast optical switching speed of the PSS-LCD, the PSS-LCD provides very wide viewing angle without birefringence averaging in space domain.

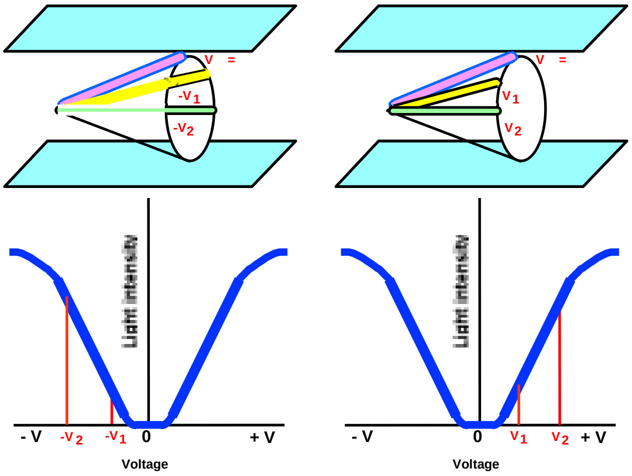

Figure 1. Molecular switching behavior of the PSS-LCD

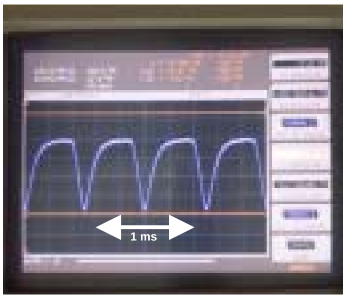

Figure 2. A typical light throughput behavior of the PSS-LCD

3.2 The initial molecular alignment

One of the unique properties of the PSS-LCD in its initial molecular alignment is its n-director molecular alignment. The PSS-LCD requires using a certain category of smectic liquid crystal molecules. The usable smectic liquid crystal molecules must have its n-director tilted from the smectic layer normal as a bulk. Using this type of smectic liquid crystal molecules, the PSS-LCD forces the n-directors normal to the smectic layer as the initial molecular alignment as illustrated in Figure 3 (a) and (b).

This n-director normal to the smectic layer is provided by strong azimuthal anchoring as well as careful cell design balanced in mechanical influence from perimeter seal materials. Due to the conceptional existence of the smectic layer structure, the display performance of the PSS-LCD is decided by the specific balance among liquid crystal materials, alignment materials and perimeter seal materials. The strong azimuthal anchoring as well as the induced polarization torque creates clear threshold voltage in the PSS-LCD. This threshold property also makes clear difference between smectic LCD using spontaneous polarization such as ferroelectric LCDs and anti-ferroelectric LCDs.

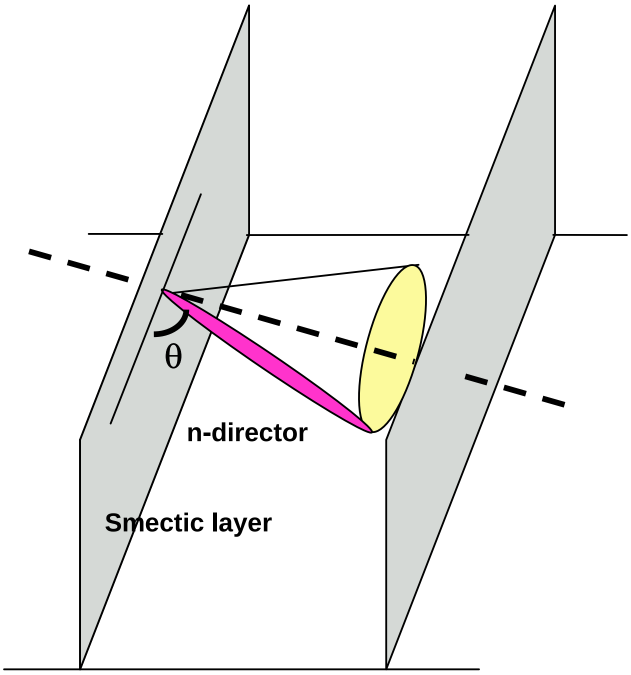

Figure 3 (a). A smectic liquid crystal whose n-director has a tilt normal to the smectic layer as a bulk is used for the PSS-LCD

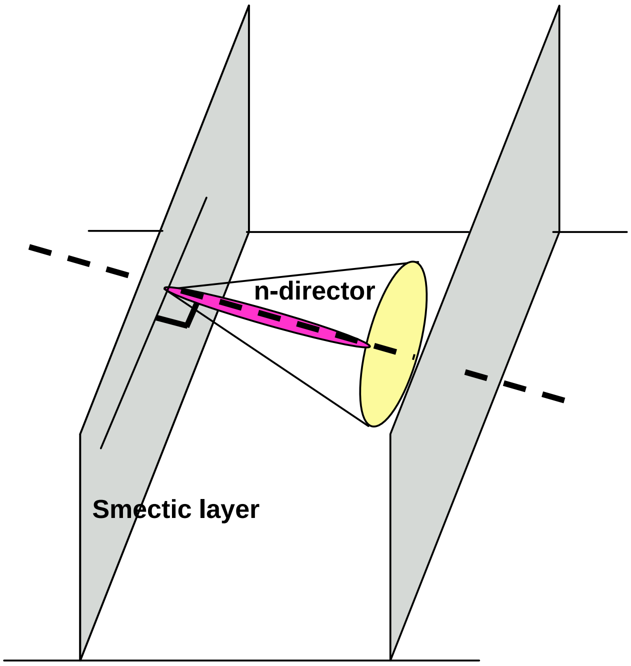

Figure 3 (b). The smectic liquid crystal whose n-director has a tilt normal to the smectic layer is initially aligned normal to the smectic layer by strong azimuthal anchoring and specific balance between the bulk alignment and mechanical matching from the perimeter seal.

3.3 Overview of the feature

The major approach of the PSS-LCD in terms of securing the high display performance is its elimination of any hysteresis in V-T curve. Other approach is to minimize pixel capacitance to fit for any types of TFTs or drive backplanes. No need to say that these approaches should also provide extremely fast optical switching speed, and native wide viewing angle as well as no need of new development of electronics.

The hysteresis free performance in V-T curve is established by the induced polarization of the smectic liquid crystal molecules. The minimum pixel capacitance is realized use of specific induced polarization of the PSS-LCD. Although the measured dielectric constant of the PSS-LC materials is very small such as $\Delta\varepsilon$ of 1.5 or 2.0, the PSS-LCD realizes extremely fast optical response due to its specific molecular movement along with cone surface. The small distance of the PSS-LC molecules' travel in the panel to create large enough birefringence provides two major benefits in terms of TFT-LCD performance. One is extremely fast optical response speed such as 100 μs with a typical driving condition. The other is very small change in pixel capacitance. These two major accomplishments by the PSS-LCD enable conventional any types of TFTs drive with some certain tolerance. Figure 4 is one of the examples of the small capacitance change before and after the optical switching of the PSS-LCD pixel.

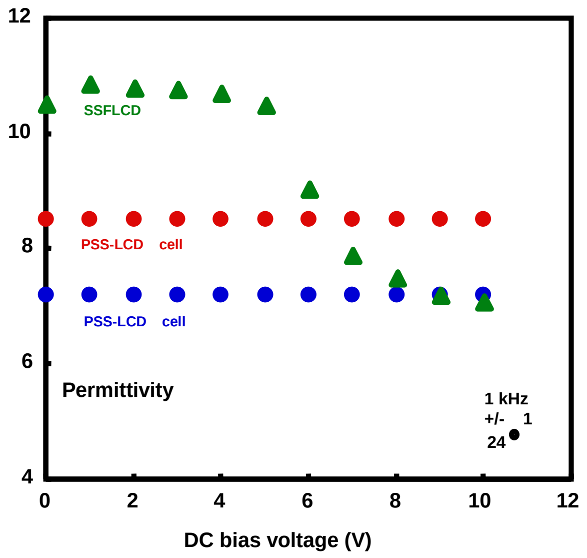

Figure 4. Dielectric change before and after the optical switching. Comparison between the SSFLCD and the PSS-LCDs

3.4 Overview in the E-O performance

Figure 5 presents a typical optical response of the PSS-LCD. As discussed above, one of the unique characteristic properties of the PSS-LCD is its much faster response in decay process than that in rise process. Moreover, the temperature dependence of the response time is very small in decay process. The rise process has some temperature dependence similar to most of nematic base LCDs; the decay process is almost independent from ambient temperature and drive voltage. This unique performance is provided by its unique initial molecular alignment. The PSS-LC molecules align tilted from the smectic layer normal as a bulk, or in nature. These molecules are forced to align the layer normal. Therefore, all of the PSS-LC molecules have a great tendency to flip back to the tilted layer normal. This energy is suppressed by the strong azimuthal anchoring energy. Just like a spring coil, an elongated spring coil backs to the original length immediately after the power is removed. This recovery time in a spring coil is almost independent from the elongated power. This extremely fast decay performance fits for use the PSS-LCD in a field sequential color system.

The PSS-LCD's specific molecular movement also allows extremely fast inter-gray scale response as shown in Figure 6. Although the driving torque is provided by the coupling between the applied electric field and dielectric anisotropy of the PSS-LC materials, the PSS-LC molecular movement is along with cone surface illustrated in Figure 1, making substantial large enough voltage change in the inter-gray scale driving. The smaller capacitance of the PSS-LCD allows this "dynamic" dielectric driving method effective.

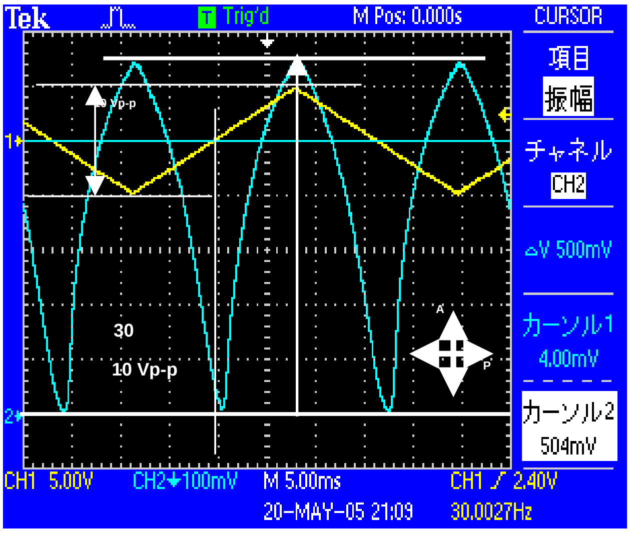

Figure 5. A typical optical response of the PSS-LCD

4. Specific design for the PSS-LCD

Unlike conventional nematic LCDs, the PSS-LCD has a conceptional smectic layer structure. This layer structure requires specific requirement in its cell design. Perimeter seal is one of the most required materials for the design of the PSS-LCD, in particular for volume manufacturing point of view.

The strong azimuthal anchoring energy mostly provided by surface anchoring layer needs to have a specific balance to keep c-director of the PSS-LC molecules uniform. If the specific balance between the surface anchoring and mechanical stress caused by mechanical performance of the perimeter seal does not match enough, c-director of the PSS-LC molecules may have some twist, resulting in degradation of the display performance. Therefore, in the design of the PSS-LCD, perimeter seal design is the one of the key issues.

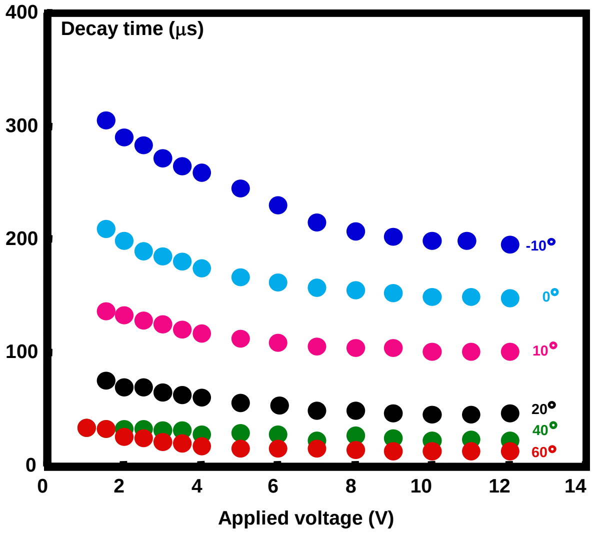

Figure 6. Decay times of the PSS-LCD depending on temperature and driving voltage which suggests inter-gray scale response times

5. Summary of the features

The similarity and difference from known LCDs are summarized in Table 1. As shown in the Table 1, the PSS-LCD has been fully inherited from current major nematic base TFT-LCDs in its electrical drive portion.

The V-T curve of the PSS-LCD is same with that of TN-LCDs. Therefore, current commercially available drive LSI and controllers are available to drive the PSS-LCDs as they are. The extremely fast optical response speed without increase in capacitance would offer some more capabilities in driver LSIs.

On the other hand, the molecular movement is somewhat similar with an SSFLCD. The largest difference in the molecular movement between the SSFLCD and the PSS-LCD is their molecular tilt configuration. Due to spontaneous polarization, the stable tilt angle of the SSFLC is decided by the strength of the polarization. The strength of the polarization is a function of ambient temperature. Therefore, the initial molecular alignment of the SSFLCD is dependent on ambient temperature. Unlike this situation, the extinction angle of the PSS-LCD is decided by the initial molecular alignment pre-set by molecular alignment direction. The distinction angle of the PSS-LCD is independent from ambient temperature. Moreover, due to the induced polarization nature, the PSS-LC molecules keep their specific tilt angle on the cone surface solely by the coupling between the applied electric field and the induced dielectric anisotropy of the liquid crystals.

Table 1. A general comparison

	PSS-LCD	SSFLCD	TN-LCD
Liquid Crystals	Smectic C LCs	Ferroelectric LCs	Nematic LCs
Alignment	Homogeneous	Homogeneous	Twisted
Initial director alignment	Parallel to buffing direction	Tilted by a half cone angle from buffing direction	Parallel to buffing direction
Typical cell gap	1.8 μm	2 μm	4 μm
Spontaneous polarization	No	Yes	No
Driving torque	Induced polarization	Spontaneous polarization	Induced polarization
Permittivity change by drive	$\Delta\varepsilon$	2Ps	$\Delta\varepsilon$

5. Concluding remarks

The PSS-LCD is proposed under the condition of realistic requirement of given circumstance from industry. Full compatibility of current established electronics for LCDs allows potentially wide flexible use of the PSS-LCDs. Moreover, most of LC panel manufacturing process is compatible with current dominant LCD mfgs. Even some of mfg process is simpler than those of current one, in particular, free from pixel division for wide viewing angle.

6. Acknowledgements

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7. References

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